

CEPHALOPODS FROM THE
CRETACEOUS/TERTIARY BOUNDARY
INTERVAL ON THE ATLANTIC COASTAL
PLAIN, WITH A DESCRIPTION OF THE
HIGHEST AMMONITE ZONES IN
NORTH AMERICA.
PART 2. NORTHEASTERN MONMOUTH
COUNTY, NEW JERSEY

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CONTENTS

Abstract	3
Introduction	3
Stratigraphic Setting	4
Navesink Formation	5
Red Bank Formation	5
Tinton Formation	6
New Egypt Formation	6
Hornerstown Formation	6
Previous Reports of Ammonites	7
List of Localities	7
Methods	8
Description of New Localities	9
Lithostratigraphic Relationships	19
Molluscan Biostratigraphy	21
Dinoflagellate Biostratigraphy	23
Background	23
Occurrences of Dinoflagellates	25
Biostratigraphic Synthesis	30
Iridium Analysis	31
Strontium Analysis	31
Cretaceous/Tertiary Boundary	32
Main Fossiliferous Layer	34
<i>Discoscaphites iris</i> Zone	37
Paleogeography at the K/T Boundary	39
Systematic Paleontology	39
Conventions	39
Genus <i>Eutrephoceras</i> Hyatt, 1894	41
<i>Eutrephoceras dekayi</i> (Morton, 1834)	41
Genus <i>Sphenodiscus</i> Meek, 1871	50
<i>Sphenodiscus pleurisepta</i> (Conrad, 1857)	50
<i>Sphenodiscus lobatus</i> (Tuomey, 1856)	51
<i>Sphenodiscus</i> spp.	55
Genus <i>Eubaculites</i> Spath, 1926	55
<i>Eubaculites carinatus</i> (Morton, 1834)	55
<i>Eubaculites latecarinatus</i> (Brunnschweiler, 1966)	63
Genus <i>Discoscaphites</i> Meek, 1871	71
<i>Discoscaphites iris</i> (Conrad, 1858)	71
<i>Discoscaphites minardi</i> Landman et al., 2004	89
<i>Discoscaphites gulosus</i> (Morton, 1834)	92
<i>Discoscaphites</i> spp.	94
Acknowledgments	95
References	96
Appendix 1	106

ABSTRACT

The sedimentary deposits of the New Jersey Coastal Plain span the Cretaceous/Tertiary boundary and reveal a complex stratigraphy in the northeastern part of their outcrop belt. Newly discovered exposures of the New Egypt Formation in northeastern Monmouth County, New Jersey, indicate that a tongue of this formation, previously thought to be restricted in outcrop to southwestern Monmouth County, extends to the northeast. This formation is sandwiched between the Tinton Formation below and the Hornerstown Formation above. The upper contact is unconformable. Fossils occur in the upper part of the New Egypt Formation and the basal part of the Hornerstown Formation and are concentrated at the formational contact—this accumulation is known as the Main Fossiliferous Layer. The *Discoscaphites minardi* Assemblage Zone occurs in the New Egypt Formation approximately 2 m below the base of the Hornerstown Formation and contains *Discoscaphites minardi* Landman et al., 2004, *Discoscaphites* sp., *Eubaculites carinatus* (Morton, 1834), *Eubaculites* sp., and *Eutrephoceras dekayi* (Morton, 1834). Associated dinoflagellates include *Deflandrea galatea* (Lejeune-Carpentier, 1942) Lentin & Williams, 1973, and *Thalassiphora pelagica* (Eisenack, 1954) Eisenack & Gocht, 1960. The *D. minardi* Zone represents the middle part of the upper Maastrichtian corresponding to the upper part of calcareous nannofossil Subzone CC26a and the lower part of Subzone CC26b. The *Discoscaphites iris* Assemblage Zone occurs at the top of the New Egypt Formation in an interval at least 20 cm thick and contains *Discoscaphites iris* (Conrad, 1858), *Discoscaphites gulosus* (Morton, 1834), *D. minardi*, *Eubaculites latecarinatus* (Brunn-schweiler, 1966), *E. carinatus*, *Sphenodiscus pleurisepta* (Conrad, 1857), *Sphenodiscus* sp., and *Eutrephoceras dekayi*. Associated dinoflagellates include *Palynodinium grallator* Gocht, 1970, and *T. pelagica*. The *D. iris* Zone represents the uppermost Maastrichtian, corresponding to the upper part of calcareous nannofossil Zone CC26b. The basal beds of the Hornerstown Formation contain a mixed assemblage of Cretaceous and Paleocene fossils. Paleocene dinoflagellates include *Carpateella cornuta* Grigorovich, 1969, and *Senoniasphaera inornata* (Drugg, 1970) Stover & Evitt, 1978, and suggest that these beds correspond to planktonic foraminiferal zones PO–P α . There is no enrichment of iridium (≥ 0.1 ppb) or layer of spherules at the formational contact but a dinoflagellate specimen with pockmarked damage consistent with melting is present in the top of the New Egypt Formation. The formational contact spans the Cretaceous/Tertiary boundary but probably contains a hiatus of approximately 100 k.y. All of the Cretaceous fossils in the Main Fossiliferous Layer are reworked from the upper New Egypt Formation and reflect a period of erosion and winnowing, perhaps related to changes in sea level as well as events associated with the bolide impact at the end of the Cretaceous. Subsequently and simultaneously, the sea floor experienced extensive bioturbation, which may have further reworked fossils. Elsewhere on the Gulf and Atlantic Coastal Plain, the *D. iris* Zone also occurs immediately below the K/T boundary and is truncated by an erosional unconformity, commonly with reworked material in the overlying beds. The geographic distribution of the *D. iris* Zone and cores spanning the K/T boundary on the Gulf and Atlantic Coastal Plains help approximate the coastline of North America at that time and indicate a broad Mississippi embayment. However, there is no firm evidence that the Western Interior Seaway persisted until the end of the Cretaceous.

INTRODUCTION

The Monmouth Group of New Jersey consists of a sequence of formations that crop out in a narrow northeast–southwest belt across the center of the state (fig. 1). The formations are Campanian to Maastrichtian in age and represent a transgressive-regressive cycle showing a transition from middle shelf, glauconitic clays to upper-to-lower shoreface, quartzose sands (Owens and Sohl, 1969). The classic sequence consists of, in

ascending stratigraphic order, the Mount Laurel Formation, the Navesink Formation, the Red Bank Formation, and the Tinton Formation (fig. 2). The New Egypt Formation has been interpreted as the downdip equivalent of the Red Bank and Tinton formations (Koch and Olsson, 1977). The Tinton Formation is overlain unconformably by the Hornerstown Formation, the basal member of the Rancocas Group.

The Cretaceous/Tertiary boundary has been identified at the base of the Horner-

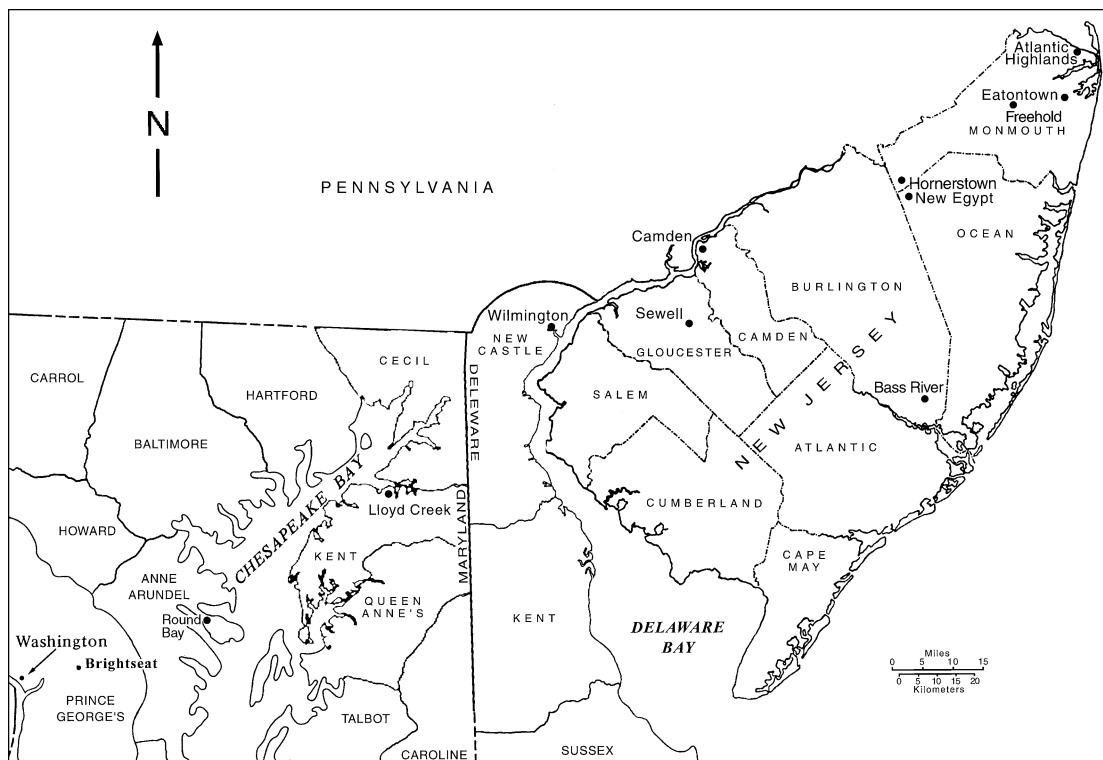


Fig. 1. Map of parts of New Jersey and Maryland showing localities mentioned in text.

town Formation using macro- and microfossils (Minard et al., 1969; Gallagher, 1993; Olsson et al., 1997). However, the precise position of this boundary has been debated. A rich fauna of vertebrates and invertebrates occurs at the base of the Hornerstown Formation and has been dubbed the “Bone Bed” (Koch and Olsson, 1977) or Main Fossiliferous Layer (Gallagher, 1993).

In this paper, the second in a series of four papers on Maastrichtian ammonites from the Atlantic Coastal Plain, we investigate the lithostratigraphic and biostratigraphic relationships among the Upper Cretaceous strata of New Jersey based on newly discovered exposures in northeastern Monmouth County. We reexamine the position of the Cretaceous/Tertiary boundary and discuss the origin of the Main Fossiliferous Layer. We are particularly interested in the cephalopods in the upper part of the New Egypt Formation and the base of the Hornerstown Formation. These beds contain an unexpectedly rich fau-

na of *Discoscaphites*, all the more astonishing because only one specimen of this genus was known from New Jersey prior to this study (Kennedy et al., 2000). These ammonites represent the *Discoscaphites iris* Assemblage Zone, the highest ammonite zone in North America.

STRATIGRAPHIC SETTING

Doing geologic fieldwork in New Jersey today is challenging. Because of the spread of urbanization, fewer and fewer outcrops of Upper Cretaceous strata are available for study. In addition, the outcrops that exist are invariably small and discontinuous, making it very difficult to locate oneself within a section and to correlate with other, equally small, isolated outcrops. Furthermore, most of the historically important fossils described in the 19th century were collected at sites of mining operations for greensand (Gallagher, 1995). All of these sites, with one notable

Tertiary	Rancocas Group (part)	Hornerstown Fm		
Cretaceous	Monmouth Group	Tinton Fm		New Egypt Fm
		Red Bank Fm	Shrewsbury Member	
			Sandy Hook Member	
		Navesink Fm		
		Mount Laurel Fm		

Fig. 2. Standard stratigraphic sequence of part of the Upper Cretaceous and Lower Tertiary succession in Monmouth County, New Jersey (reproduced from Olsson, 1987). In earlier interpretations (Olsson, 1963), the New Egypt Formation was also considered to be equivalent to parts of the Hornerstown and Navesink formations.

exception, the Inversand Pit at Sewell, Gloucester County, are now closed.

The Upper Cretaceous stratigraphy of New Jersey has been worked out over the last nearly 150 years (see Gallagher, 1993, for a list of the classic references). We review below the formations in the upper part of the Monmouth Group and lower part of the Rancocas Group to provide a background for our study (fig. 2).

NAVESINK FORMATION

The Navesink Formation crops out in a number of localities in Monmouth County, where it is a burrow-mottled, light to dark gray, glauconitic, clayey sand to sandy clay. According to Olsson (1963: 649), it is approximately 10–11.5 m thick in the northern portion of the Coastal Plain but thins south-

ward to approximately less than 3 m, disappearing altogether north of Delaware. The most common macrofossils are *Exogyra costata* Say, 1820, *Pycnodonte convexa* (Say, 1820), *Agerostrea mesenterica* (Morton, 1834), *Choristothyris plicata* (Say, 1820), and *Belemnitella americana* (Morton, 1830). A pervasive layer of reworked phosphatic internal molds occurs at the base of the formation (Cobban, 1974; Kennedy et al., 2000). In northeastern Monmouth County, the Navesink Formation grades upward into the Sandy Hook Member of the Red Bank Formation. In the Crosswicks Creek Drainage, southwestern Monmouth County, the Navesink Formation grades upward into the New Egypt Formation (Olsson, 1963). Gallagher (1993) identified the Navesink Formation at the Inversand Pit, Gloucester County, but pointed out that the lithology at this site is different from that of the Navesink Formation in northeastern Monmouth County. Koch and Olsson (1977), whose usage we follow, called the unit at the Inversand Pit the New Egypt Formation (see below). Olsson (1975) interpreted the Navesink Formation as a transgressive deposit that accumulated on the midshelf.

RED BANK FORMATION

The Red Bank Formation is restricted to northeastern Monmouth County. Olsson (1960) divided it into two members, the Sandy Hook Member below and the Shrewsbury Member above. The Sandy Hook Member is approximately 3–11.5 m thick and is a dark gray, micaeous, silty, fine grained, feldspathic quartz sand (Olsson, 1963). Macrofossils occur as original shells and as internal molds. Olsson (1975) interpreted this member as a regressive unit that was deposited on the inner to mid-shelf. The Sandy Hook Member grades downward into the Navesink Formation and upward into the Shrewsbury Member. The Shrewsbury Member is approximately 33 m thick and is a fine- to medium-grained, micaceous, feldspathic quartz sand (Olsson, 1963). It is bright yellowish to reddish brown on weathered exposures, but dark gray on fresh exposures. It contains few fossils, probably due to poor preservation.

TINTON FORMATION

The Tinton Formation is a glauconitic quartz sand. It is reddish brown to yellowish brown in weathered outcrops but blackish gray in unweathered outcrops (Minard et al., 1969). It is commonly cemented and encrusted by iron oxide. Minard et al. (1969) estimated the thickness of the Tinton Formation as approximately 6.5 m at its type locality near Tinton Falls, Monmouth County, and described it as grading downward into the Red Bank Formation. In contrast, Sugarman et al. (1995) described the lower contact as disconformable, which more closely agrees with our own observations. The Tinton Formation is well exposed in the northeastern part of Monmouth County but is also present in the Manasquan River Drainage, central Monmouth County, where it is characterized by siderite nodules in its upper part (Landman et al., in prep. a). This type of lithology extends to the northeastern reaches of the Crosswicks Creek Drainage, but the Tinton Formation is rapidly replaced toward the southwest by the New Egypt Formation (Landman et al., in prep. b). The Tinton Formation contains internal molds of molluscs, crab claws, and the trace fossil *Ophiomorpha* at its type locality but is much more fossiliferous in the Manasquan River Drainage (Landman et al., in prep. a). Olsson (1975) interpreted the Tinton Formation as having been deposited in an inner shelf environment.

NEW EGYPT FORMATION

The New Egypt Formation was first defined by Olsson in 1960 and described more fully by him in 1963 for outcrops in the New Egypt area along the banks of Crosswicks Creek and its tributaries. The New Egypt Formation is dark gray, glauconitic, clayey sand to sandy clay. Siderite nodules occur in certain layers and mica and lignite are common minor constituents. The formation is approximately 10–10.5 m thick in the Crosswicks Creek area and thins to the south (Olsson, 1963). It conformably overlies the Navesink Formation and unconformably underlies the Hornerstown Formation. The New Egypt Formation has not been reported in northeastern Monmouth County (but see below).

Olsson (1963) originally interpreted the New Egypt Formation as equivalent in age to the Navesink, Red Bank, Tinton, and Hornerstown formations and representing a deeper-water facies of these units. Gallagher (1986: 15) followed this interpretation and stated that the New Egypt Formation referred to “the down-dip facies of the Navesink, Redbank, Tinton, and Hornerstown formations or to the exposures along Crosswicks Creek in the New Egypt type area in southern Monmouth County.” Olsson (1987: fig. 2) later restricted the New Egypt Formation to only the downdip equivalent of the Tinton and Red Bank formations (fig. 2).

Lithologically, the New Egypt Formation closely resembles the Navesink Formation, making it difficult to distinguish between these two units. However, the Navesink Formation is light gray in color, with a slightly coarser matrix and a little more glauconite than the New Egypt Formation. The New Egypt Formation is commonly brownish in color, which gives the formation its informal name of “Chocolate Marl”. Siderite is restricted to the basal portion of the Navesink Formation whereas it occurs throughout much of the New Egypt Formation. Outcrops southwest of the Crosswicks Creek area closely match the lithology of the New Egypt Formation in its type locality, whereas the typical Navesink lithology appears to be limited in outcrop to Monmouth County, although scattered outcrops of it may exist to the southwest.

HORNERSTOWN FORMATION

The Hornerstown Formation is burrow-mottled, glauconitic clayey sand. The abundant glauconite produces a dark greenish color, giving the formation its informal name of “Greensand Marl”. The Hornerstown Formation is a persistent unit that can be traced along the entire outcrop belt from Monmouth County, New Jersey, to Maryland (Minard et al., 1969). Olsson (1963) interpreted the formation as having been deposited in midneritic depths. Minard (1969) estimated that the Hornerstown Formation is approximately 1.5–5 m thick in northeastern Monmouth County and approximately 10 m thick in the Crosswicks Creek area. Olsson (1963) stated

that the Hornerstown Formation unconformably overlies the Tinton Formation in north-eastern Monmouth County and unconformably overlies the New Egypt Formation in the New Egypt area as well as at the Inversand Pit. The base of the Hornerstown Formation contains a concentrated fossil bed known as the “Bone Bed” (Koch and Olsson, 1977) or “Main Fossiliferous Layer” or “MFL” for short (Gallagher, 1993).

PREVIOUS REPORTS OF AMMONITES

Several ammonite species have been reported from the upper Maastrichtian strata of New Jersey. Kennedy and Cobban (1996: fig. 2.4–2.6, 2.13, 2.14, 2.19–2.21) reported fragments of *Sphenodiscus lobatus* (Tuomey, 1856) from the Inversand Pit near Sewell, Gloucester County. Internal molds of this species also occur in the New Egypt Formation at Crosswicks Creek, southwestern Monmouth County (Olsson, 1963; Kennedy et al., 2000), the upper part of the Navesink Formation (New Egypt Formation according to our usage) and the basal part of the Hornerstown Formation at the Florentine Pit, southwestern Monmouth County (Minard et al., 1969), and the Tinton Formation, north-eastern Monmouth County (Weller, 1907: pl. 106, figs. 1, 2; Reeside, 1962: pl. 75, fig. 3; Olsson, 1963; Minard et al., 1969; Gallagher, 1993; Kennedy et al., 1995). Kennedy et al. (1995) stated that this species is also present in the Red Bank Formation, but to our knowledge, no such specimens exist.

Kennedy and Cobban (1996: figs. 2.1–2.3, 3.4–3.6) described eight specimens of *Baculites* spp., seven from the Inversand Pit and one from the base of the Hornerstown Formation on the west bank of Crosswicks Creek, southwestern Monmouth County. Kennedy et al. (2000: fig. 7A–F) reported three specimens of *Baculites* sp., two from the Inversand Pit and one from near the base of the New Egypt Formation at a nearby outcrop along the banks of Chestnut Branch Creek, near Sewell, Gloucester County. Additional baculites from the Inversand Pit are housed in the collections of the New Jersey State Museum. Kennedy and Cobban (1996: fig. 3.1–3.3, 3.7–3.12) reported three specimens of *Eubaculites carinatus* (Morton,

1834) from an unspecified site in New Jersey inferred by them to be from the base of the Hornerstown Formation. Olsson (1963: 646, NJT51) also reported this species from the New Egypt Formation in a south-flowing tributary of Lahaway Creek in the northern portion of the New Egypt area. Minard et al. (1969) identified *Baculites* sp. and what they called *Baculites columna* from the base of the Hornerstown Formation at approximately this same site.

Kennedy and Cobban (1996: fig. 2.7–2.12, 2.15–2.18) described fragments of *Pachydiscus* (*Neodesmoceras*) *mokotibensis* (Collignon, 1952) from the Main Fossiliferous Layer at the Inversand Pit. Kennedy et al. (2000: fig. 9G–I) reported a single specimen of *Discoscaphites gulosus* (Morton, 1834) from the spoil pile at the Inversand Pit, which, on the basis of its preservation, was probably derived from the lower part of the New Egypt Formation (W. Gallagher, personal commun., 2003; mistakenly listed as *Discoscaphites conradi* [Morton, 1834] in Gallagher [2002: appendix]).

LIST OF LOCALITIES

The localities mentioned in the text are shown in Figures 1 and 3 and are described below. Numbers in parentheses are U.S. Geological Survey Paleobotanical localities.

AMNH loc. 3345 (R6234A–D). Upper part of the New Egypt Formation and lower part of the Hornerstown Formation, Parkers Creek, including a small side tributary, 0.3 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey. R6234D: 5–10 cm below the base of the Hornerstown Formation; R6234C: 0–5 cm below the base of the Hornerstown Formation; R6234A: 0–5 cm above the base of the Hornerstown Formation; R6234B: 5–10 cm above the base of the Hornerstown Formation.

AMNH loc. 3346 (R6234E). New Egypt Formation, approximately 1.5–2.0 m below the base of the Hornerstown Formation, Parkers Creek, 0.1 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

AMNH loc. 3347. New Egypt Formation, approximately 1.5–2 m below the base of the Hornerstown Formation, Parkers Creek, 0.3

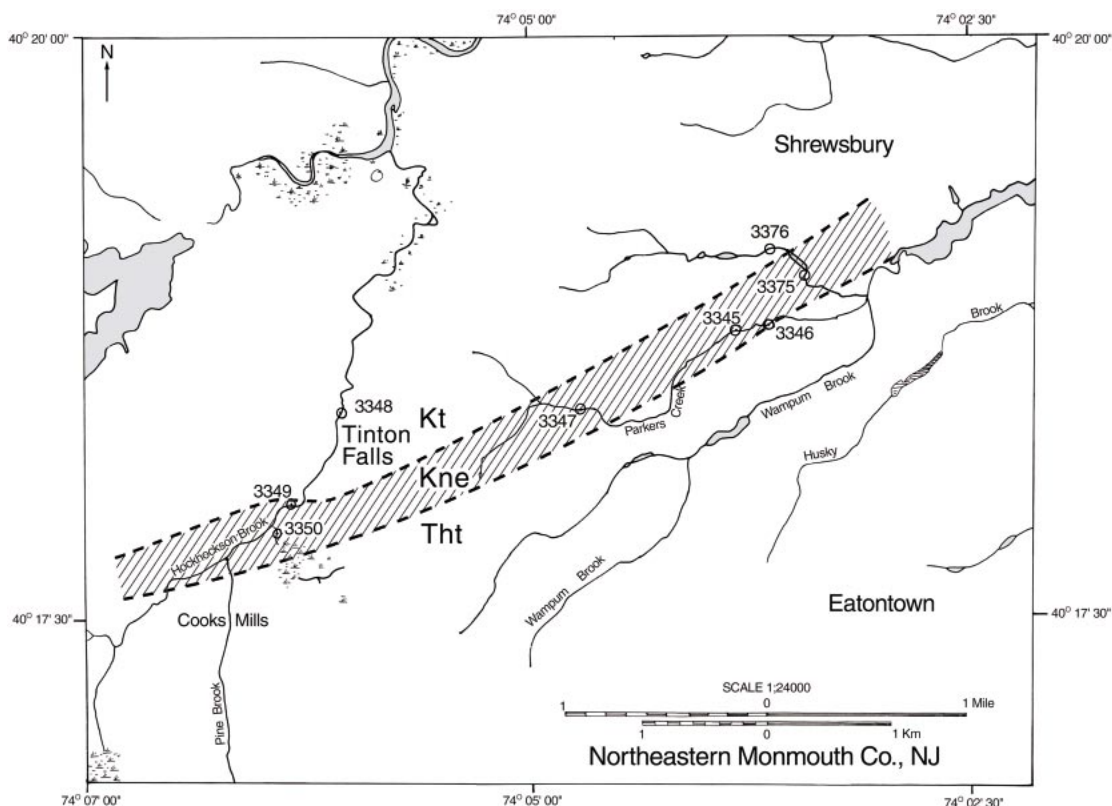


Fig. 3. Detailed locality map of northeastern Monmouth County, New Jersey, showing the areal extent of the New Egypt Formation (Kne) and its contact with the underlying Tinton formation (Kt) and overlying Hornerstown Formation (Tht). Numbers correspond to those in the list of localities.

km east of Hope Road, northwest of Eatontown, Monmouth County, New Jersey.

AMNH loc. 3348 (R6234H). Tinton Formation, Hockhockson Brook, 0.2 km north of the intersection of Water Street and Tinton Avenue, including a temporary construction site for widening the Garden State Parkway, approximately 1.25 km downstream, Monmouth County, New Jersey.

AMNH loc. 3349 (R6234G). Upper part of the Tinton Formation and lower part of the New Egypt Formation, Hockhockson Brook, 0.5 km southwest of the intersection of Water Street and Tinton Avenue, Monmouth County, New Jersey.

AMNH loc. 3350. New Egypt Formation, southern tributary to Hockhockson Brook, 0.7 km southwest of the intersection of Water

Street and Tinton Avenue, Monmouth County, New Jersey.

AMNH loc. 3375. New Egypt Formation, east-flowing tributary to Parkers Creek, 0.3 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

AMNH loc. 3376. Tinton Formation, east-flowing tributary to Parkers Creek, 0.6 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

METHODS

Fossils were recovered at the outcrop by hand picking and by sieving. Where possible, the fossiliferous beds were exposed by creating a bench. Screwdrivers were used to break off chunks of rock about 15–20 cm in

size to reveal fossils. Unproductive chunks and smaller pieces were then sieved with water using a screen with 1/4-in. mesh. In some instances, window screens were used to recover finer material. Fossils were subsequently fixed with a solution of Elmer's glue and water or Alvar and acetone.

Samples for sedimentological, geochemical, and microfossil analyses were taken at 5-cm intervals across the outcrop using plastic spoons. For the sedimentological analysis, a portion of sediment was dried out and approximately 15 g were removed for weighing. The weighed sample was placed in 100 ml of calgon solution (3 g/1000 ml deionized water) and left for several days. The sample was then sonified in distilled water and rinsed through a series of three screens with 0.25-mm, 0.125-mm, and 0.0625-mm mesh. If large clumps of mud remained after screening, the sediment was further disaggregated by stirring and crushing with a plastic utensil under a binocular microscope. The process of crushing, sonifying, and rinsing was repeated until the water of the sonified sample was clear to slightly turbid—but not opaque—after several minutes of sonifying. Finally, the sediment on each of the three screens was transferred to filter paper for drying for several days and then weighed. The results are reported as mud ($X < 0.0625$ mm), very fine sand ($0.0625 \text{ mm} \leq X < 0.125$ mm), fine sand ($0.125 \text{ mm} \leq X < 0.25$ mm), and medium sand ($X \geq 0.25$ mm). For the mineralogical analysis, approximately 100 grains within each size fraction were examined under the microscope. The number of grains of glauconitic minerals, mica, and other minerals (quartz, etc.) was counted and reported as a percentage of the total.

Aliquots of dried sediment were also analyzed for total and particulate organic carbon using a Carlo Erba CHN Analyzer. Analytical error based on instrumentation blanks and replicate analyses was 2%. Carbon is expressed as a percentage of the total mass of dried sediment (mean $\pm$ 1 standard deviation of the replicate). The total carbon includes both organic carbon and carbon in calcic carbonate. Samples were subsequently acidified, dried, and reanalyzed to determine the percentage of organic carbon.

DESCRIPTION OF NEW LOCALITIES

On the basis of small, discontinuous, but closely spaced outcrops, we assembled a composite stratigraphic section near Eatontown, northeastern Monmouth County. This section was pieced together by taking into account the angle of dip (25 ft/mi for Cretaceous strata in New Jersey; Gallagher, personal commun., 2003) and walking out stream exposures over approximately 7 km². The section consists of, in ascending stratigraphic order, the Tinton Formation, the New Egypt Formation, and the Hornerstown Formation, which are approximately 6.5 m, 5–6.5 m, and 6.5–10 m thick, respectively (figs. 4, 5). We collected macrofauna and samples for dinoflagellates. None of the sites preserves nannofossils (J.M. Self-Trail, personal commun., 2003), presumably due to leaching.

The Tinton Formation is exposed at its type locality at AMNH loc. 3348 (approximately 40 ft above sea level). According to Minard et al. (1969), the Tinton Formation is approximately 6.5 m thick at this site but, based on observations of recent construction excavations, it may be slightly thicker. Specimens of *Sphenodiscus lobatus* and *Eutrophoceras dekayi* (Morton, 1834) were collected from approximately the middle of the formation. Associated dinoflagellates are moderately diverse with good preservation (table 1, figs. 6–9) and include *Deflandrea galatea* (Lejeune-Carpentier, 1942) Lentin & Williams, 1973, and *Isabelidium cooksoniae* (Alberti, 1959) Lentin & Williams, 1977, *sensu lato*. No single species dominates.

The exposures at Hockhockson Brook reveal that the streambed is floored by the Tinton Formation. Approximately 0.5–1 m of the New Egypt Formation is visible above 0.5 m of the Tinton Formation at AMNH loc. 3349 (approximately 40 ft above sea level); the contact appears gradational. The dinoflagellates from the upper part of the Tinton Formation and the lower part of the New Egypt Formation are very diverse with good preservation (table 1: figs. 6–9). They include *Deflandrea galatea* and *Thalassiphora pelagica* (Eisenack, 1954) Eisenack & Gocht, 1960. No single species dominates.

In a tributary to Hockhockson Brook

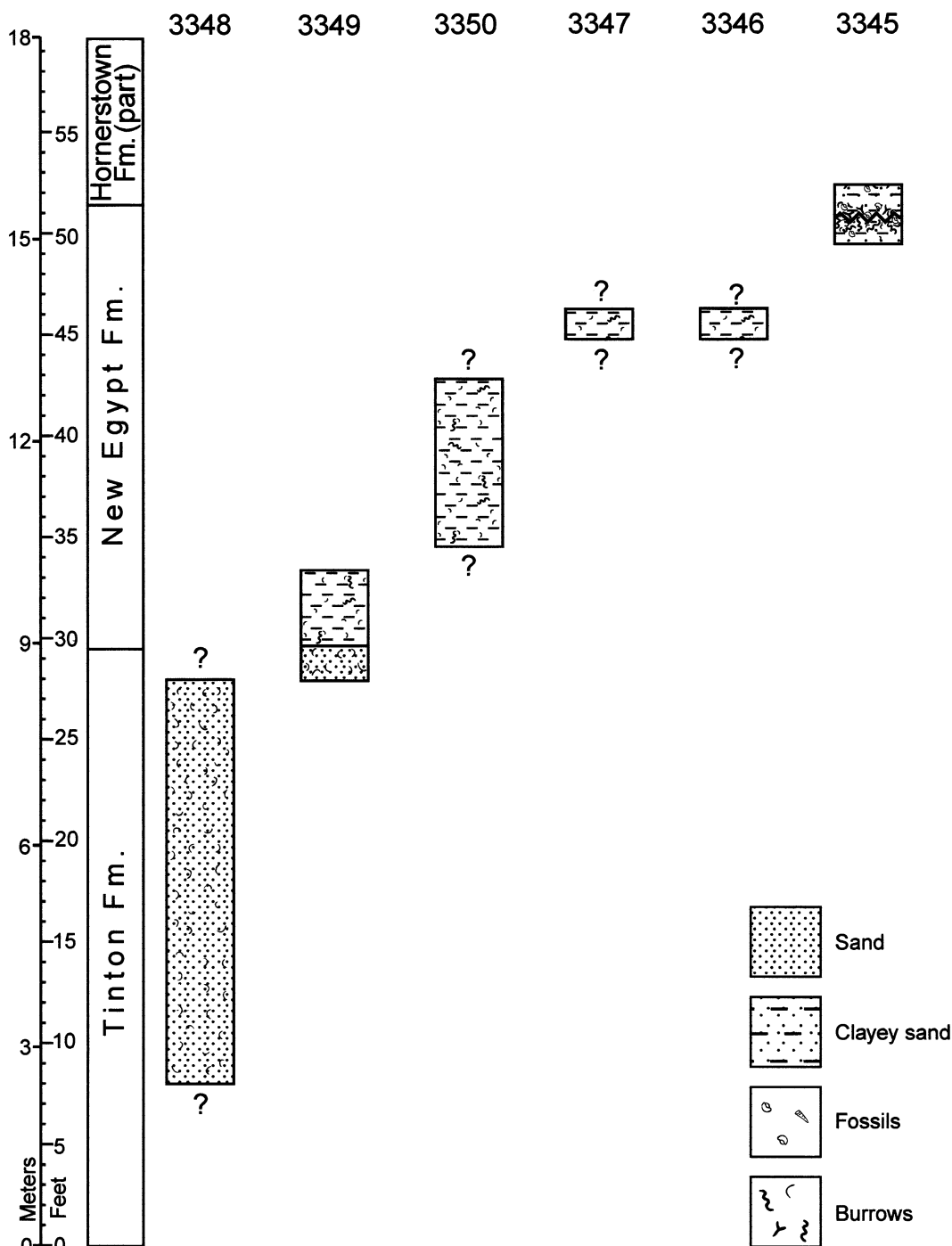


Fig. 4. Comparison of stratigraphic sections at localities in northeastern Monmouth County, New Jersey. Numbers correspond to those in the list of localities.

TABLE 1
Occurrences of Dinocyst Taxa from Northeastern Monmouth County, New Jersey^a

Taxon	3348 R6234H	3349 R6234G	3346 R6234E	3345 R6234D	3345 R6234C	3345 R6234A	3345 R6234B
<i>? Andalusella rhombohedra</i> of Edwards et al. (1984)	X		X				
<i>Alisocysta circumtabulata</i> (Drugg, 1967) Stover & Evitt, 1978				X			
<i>Allogymnium/Dinogymnium</i> sp.		X	X	X	X		
<i>Amphorosphæroidium/Cordosphaeridium</i> complex			X				
<i>Arcoligera senonenis</i> Lejeune-Carpentier, 1938, species complex		X					
<i>Arcoligera/Glaphyrocysta</i> complex	X						
<i>Carpateella cornuta</i> Grigorovich, 1969							
<i>Cerodinium striatum/diebelii</i> complex	X	X	X		X		
<i>Circulodinium distinctum</i> (Deflandre & Cookson, 1955) Jansonius, 1986, species complex	X	X	X				
<i>Connexinura finbriata</i> May, 1980		X	X				
<i>Cordosphaeridium fibrospinosum</i> Davey & Williams, 1966			X		X	X	
<i>Cribroperidinium giuseppeii</i> (Morgenroth, 1966) Helenes, 1984				X	X		
<i>Cribroperidinium</i> sp.					X		
<i>Cribroperidinium</i> spp. (includes <i>C. edwardsi/wetzelii/ventriosum</i> complex)	X	X	X				
<i>Deflandrea galatea</i> (Lejeune-Carpentier, 1942) Lentin & Williams, 1973	X	X	X	X	X	X	
<i>Disphaerogena carposphaeropsis</i> Wetzel, 1933 (= <i>Cyclapophysis monmouthensis</i>)				X			
<i>Fibradinium</i> aff. <i>F. annetorpense</i> Morgenroth, 1968							
<i>Fibradinium annetorpense</i> Morgenroth, 1968				X			
<i>Fibrocysta axialis</i> (Eisenack, 1965) Stover & Evitt, 1978				X			
<i>Fibrocysta/Danassadinium</i> intergrades					X	X	
<i>Fromea fragilis</i> (Cookson & Eisenack, 1962) Stover & Evitt, 1978		X					
<i>Glaphyrocysta</i> spp.			X				
<i>Glaphyrocysta expansa</i> (Corradini, 1973) Roncaglia & Corradini, 1997			X				
(? = <i>G. perforata</i> sensu Schiøler et al., 1997)	X			X	X	X	X
<i>Hafniasphaera fluens</i> Hansen, 1977		X					
<i>Hafniasphaera</i> sp.				X	X		
<i>Histiocysta</i> ? <i>variornata</i> Slimani, 1994				X			
<i>Hystriosphæroidium tubiferum</i> (Ehrenberg, 1838) Deflandre, 1937	X	?	X ^b				
<i>Impagadinium cristatum</i> (May, 1980) Lentin & Williams, 1981		X	X	X			
<i>Impagadinium</i> sp.							
<i>Isabeltidinium cooksoniae</i> (Alberti, 1959) Lentin & Williams, 1977, sensu lato ^c	X						
<i>Kallosphaeridium</i> sp.			X				
<i>Kleithrisphaeridium truncatum</i> (Benson, 1976) Stover & Evitt, 1978					X		

TABLE 1
Continued

Taxon	3348 R6234H	3349 R6234G	3346 R6234E	3345 R6234D	3345 R6234C	3345 R6234A	3345 R6234B
<i>Manumiella seelandica</i> (Lange, 1969) Bujak & Davies, 1983				X ^d		X	
<i>Membranigonyaulax wilsonii</i> Slimani, 1994		X					
<i>Membranosphæra maastrichtica</i> Samoilovich & Mchedlishvili, 1961	X	X					
<i>Microdinium marheinekei</i> Slimani, 1994		X				X	
<i>Operculodinium/Fibrocysta axialis</i> complex		X	X				X
<i>Palaeocystodinium australinum</i> (Cookson, 1965) Lentini & Williams, 1976, species complex			X		X		
<i>Palaeocystodinium</i> sp.	X	X					
<i>Paleoperidinium</i> sp.		X					
<i>Palaeotetradinium caudatum</i> (Benson, 1976) Stover & Evitt, 1978		X					
<i>Palynodinium grallator</i> Gocht, 1970				X	X	X	X
<i>Pervosphæridium tubuloaculeatum</i> Slimani, 1994				X			
<i>Pleiodinium magnificum</i> (Stanley, 1965) Stover & Evitt, 1978, species complex				X	X		X
<i>Pterites pentagonum</i> (May, 1980) Habib & Drugg, 1987		X		X	X		
<i>Pithonella</i> ? sp. (cf. Hultberg's)			X				X
<i>Senoniasphaera inornata</i> (Drugg, 1970) Stover & Evitt, 1978							X
<i>Spinidinium</i> ? <i>clavus</i> Harland, 1973	X			X			X
<i>Spinidinium echinoideum</i> (Cookson & Eisenack, 1960) Lentini & Williams, 1976		X					
<i>Spiniferites</i> sp.	X	X	X	X	X		X
<i>Systematophora placacantha</i> (Deflandre & Cookson, 1955) Davey et al., 1969		X					
<i>Tanyosphæridium xanthiopyxides</i> (Wetzel, 1933) Stover & Evitt, 1978		X					
<i>Thalassiphora pelagica</i> (Eisenack, 1954) Eisenack & Gocht, 1960		X	X		X	X	
<i>Tritiroidinium</i> sp.				X	X		
<i>Tritiroidinium striatum</i> Benson, 1976	X						
<i>Turnhosphaera hypoflata</i> (Yun, 1981) Slimani, 1994			X				
<i>Xenikoon australis</i> Cookson & Eisenack, 1960	X	X					
<i>Yolkinygnium elongatum</i> (May, 1977) Lentini & Vozzhennikova, 1990					X		X ^e
miscellaneous cladopyxiaceans	X ^e	X ^e	X		X		X ^e
miscellaneous small peridimiceans	X	X	X	X	X	X	X

^aSee list of localities in text.^bOperculum only.^cIncluding smooth and verrucate forms.^dIncluding specimen with distinctive star-pocked damage.^eIncluding *Microdinium* sp. A of Slimani (1994).

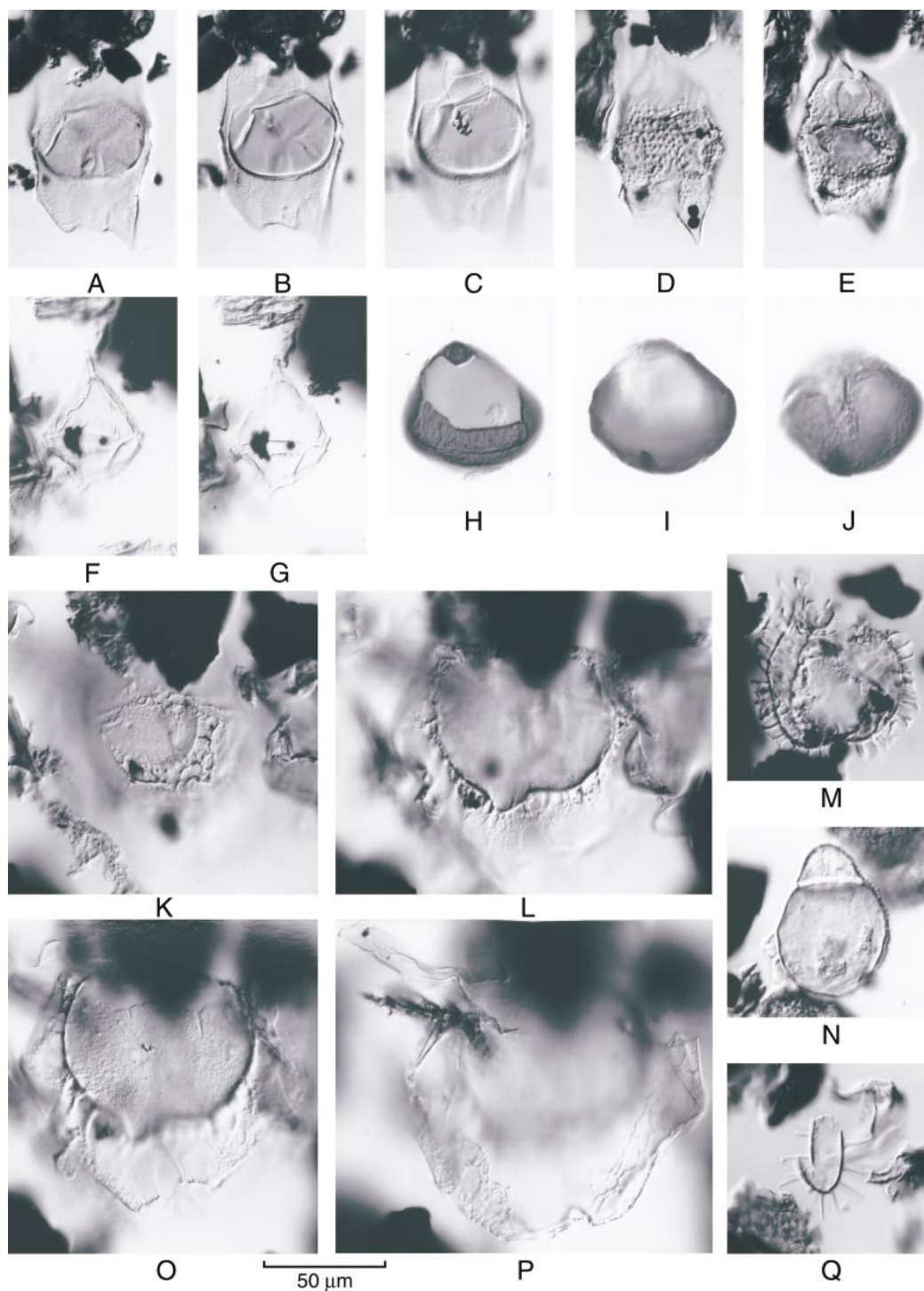


Fig. 6. Dinoflagellates from USGS Paleobotan. loc. R6234H, Tinton Formation, Hochhockson Brook, 0.2 km north of the intersection of Water Street and Tinton Avenue, northeastern Monmouth County, New Jersey. A–E. *Isabelidinium cooksoniae* (Alberti, 1959) Lentin & Williams, 1977 *sensu lato*.

approximately 1 m of the New Egypt Formation; we estimate that the base of this section is approximately 1.5–2.0 m below the base of the Hornerstown Formation by reference to the exposure containing the formational contact 100 m downstream. AMNH loc. 3345 exposes 0.2 m of the New Egypt Formation below 0.6 m of the Hornerstown Formation.

The formational contact at AMNH loc. 3345 is sharp and unconformable and consists of an uneven, highly burrowed surface bounding the chocolate brown of the New Egypt Formation and the dusky green of the Hornerstown Formation (fig. 10). Both the top of the New Egypt Formation and bottom of the Hornerstown Formation are bioturbated. Patches below the contact represent large burrows that have penetrated down into the New Egypt Formation. These burrows are part of an anastomosing three-dimensional network, although only parts of the burrows are exposed in cross section, giving the false impression that they are clasts. The burrows are purple when freshly exposed and dry to a dark greenish black (figs. 10C, 11). They consist of concentrations of large, black to very dark green, shiny, botryoidal glauconite grains, mostly in the form of fecal pellets.

Analysis of the sediments from AMNH locs. 3345 and 3346 indicates a preponderance of mud in both the top of the New Egypt Formation and bottom of the Hornerstown Formation (fig. 12A). At approximately 2 m below the base of the Hornerstown Formation, mud comprises 56% of the sediments with the rest mostly medium sand. The mud fraction remains nearly the same until just below the base, where it drops to 45% and the medium sand fraction increases proportionally. This reflects an increase in the incidence of burrows filled with large glauconite grains near and at the base. Thereafter, the mud fraction increases again, reaching a maximum of nearly 88% at 10–15 cm above the base.

Glauconitic minerals are dominant in the section (fig. 12B). They comprise 70–80% of the sand fraction in the New Egypt Formation and as much as 95% in the Hornerstown Formation. The glaucony is slightly different in the two formations. In the New Egypt Formation, the glauconite grains are mostly black to very dark green but some are yellowish brown. They range in morphology from botryoidal to accordion in shape and show well developed cracking. In contrast, the glauconite grains in the Hornerstown Formation are light to dusky green with smooth surfaces. Mica comprises a maximum of 11% of the sand fraction in the New Egypt Formation but is insignificant in the Hornerstown Formation. The percentage of quartz in the sand fraction is higher in the New Egypt Formation (5–12%) than in the Hornerstown Formation (4–8%). Quartz comprises a maximum of 36% of the very fine sand fraction 30 cm below the base of the Hornerstown Formation. In the New Egypt Formation, the mud component ($X < 0.0625$ mm) is grayish brown in color whereas it is dusky green in the Hornerstown Formation.

Aliquots of dried sediment from 0–5 cm below the base of the Hornerstown Formation and 0–5 cm above it were analyzed for total and particulate organic carbon, as described in the Methods Section. The value of total carbon is $0.69\% \pm 0.04$ below the base and $0.24\% \pm 0.02$ above the base. The value of organic carbon (after acidification) is $0.49\% \pm 0.04$ below the base and $0.18\% \pm 0.01$ above the base.

We recovered fossils at approximately 1.5–2 m below the formational contact at AMNH loc. 3346. The thickness of this fossil-bearing interval is unclear, and its lower limit is unknown. The fossils are rare, scattered, and poorly preserved. They are internal molds composed of the same material as the matrix itself. Five to 10% of the specimens are phosphatized. The faunal diversity is relatively

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F, G. *Spinidium? clavus* Harland, 1973. H–J. *Trithyroidinium striatum* Benson, 1976. K, L, O, P. *Glaphyrocysta* spp. M. *Circulodinium distinctum* (Deflandre & Cookson, 1955) Jansonius, 1986 species complex. N. *Xenikoon australis* Cookson & Eisenack, 1960. Q. *Tanyosphaeridium xanthiopyxides* (Wetzel, 1933) Stover & Evitt, 1978.

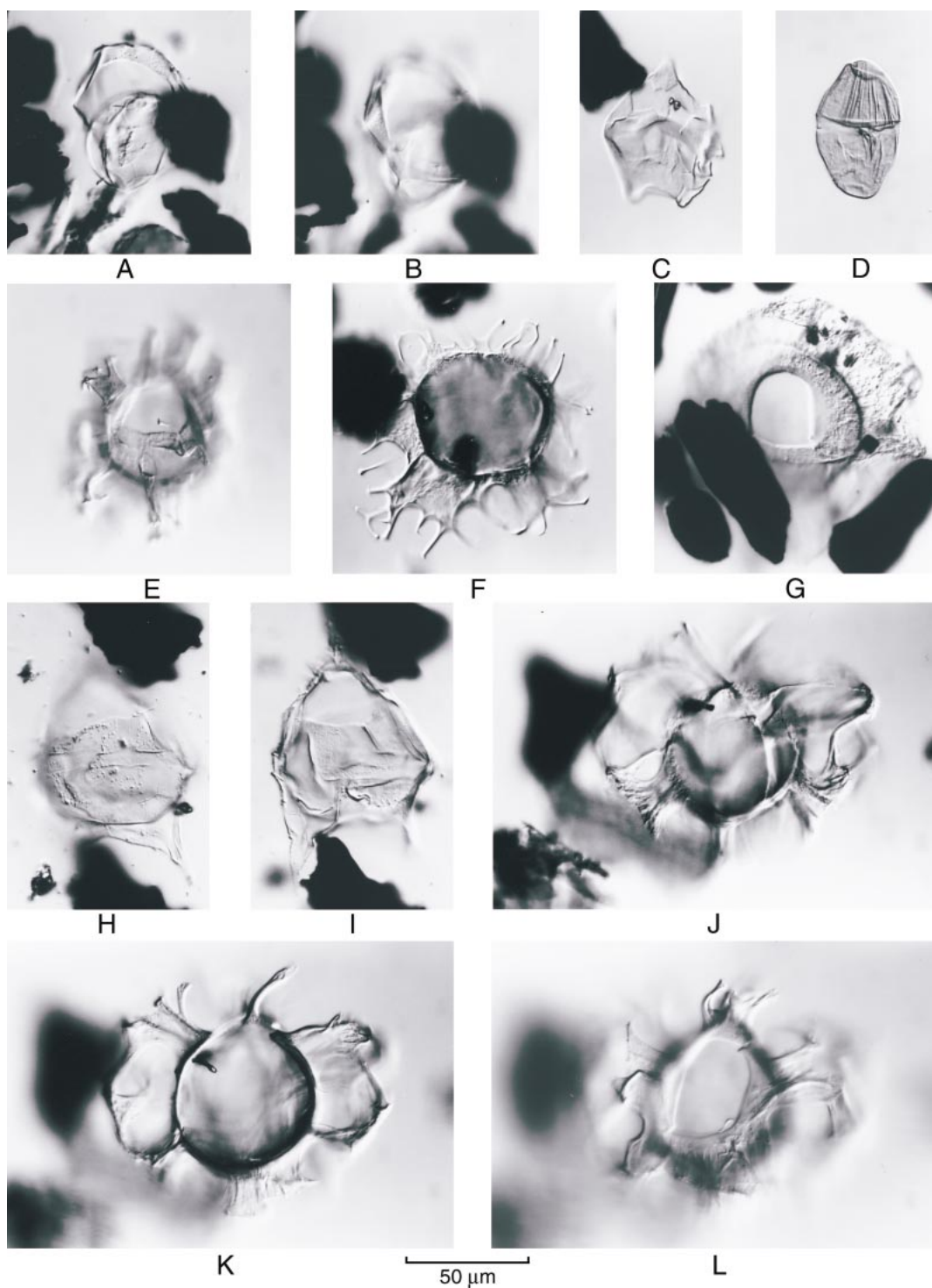


Fig. 7. Dinoflagellates from northeastern Monmouth County, New Jersey. **A, B, H, I.** USGS Paleobotan. loc. R6234E, New Egypt Formation, approximately 1.5–2.0 m below the base of the Hornerstown Formation, Parkers Creek, 0.1 km east of Rt. 35, northwest of Eatontown. **C, F, G.** USGS Paleobotan.

high. The species are listed in table 2 and consist mostly of molluscs including *Discoscaphites minardi* Landman et al., 2004. Dinoflagellates from this interval are moderately abundant with fair to good preservation (table 1; figs. 6–9). No single species dominates. The species include *Deflandrea galatea* and *Thalassiphora pelagica*.

Fossils occur in the top of the New Egypt Formation in an interval at least 20 cm thick at AMNH loc. 3345 (fig. 11). This fossil-bearing unit may actually be thicker but the rest of the formation is not exposed at this site. The majority of fossils occur at the formational contact, which constitutes the Main Fossiliferous Layer (MFL) at the base of the Hornerstown Formation, although even here, the fossils are not extremely abundant. Fossils are rare in the basal Hornerstown Formation up to approximately 20 cm above the contact. Most fossils were collected in place but some were found as float in the streambed and may have come from either the top of the New Egypt Formation or the bottom of the Hornerstown Formation.

The diversity of Cretaceous molluscs from the top of the New Egypt Formation and the basal part of the Hornerstown Formation is approximately the same as in the assemblage 1.5–2 m below the contact. The species are listed in table 3 and include *Discoscaphites iris* (Conrad, 1858). The most common fossils in the MFL are baculites and snails. The MFL also contains sharks' teeth and turtle fragments.

All of the molluscs are preserved as internal molds with New Egypt Formation lithology. This applies to specimens from the top of the New Egypt Formation, the MFL, and the basal part of the Hornerstown Formation. There are commonly burrows inside the internal molds composed of concentrations of

large glauconite pellets. All of the scaphites and baculites are incomplete. The largest baculite fragment is 75 mm in length but most are smaller. Some baculites retain shell material on their septa and some scaphites retain a very thin layer of shell material on their outer surface. Specimens of *Cucullaea vulgaris* Morton, 1830 generally occur as double valves but never in life position. None of the specimens of *Pycnodonte convexa* is preserved with original shell, contrary to the situation in other exposures of the upper part of the New Egypt Formation (Landman et al., in prep. b).

The fossils in the upper part of the New Egypt Formation show a range in preservation. For example, there are phosphatic nodules with scaphite and baculite impressions. In contrast, the fossils in the MFL and basal part of the Hornerstown Formation show a uniformly robust preservation with only three-dimensional fossils. All of the fossils in the MFL and the basal part of the Hornerstown Formation are phosphatized, whereas only 5–10% of the fossils in the upper part of the New Egypt Formation are phosphatized.

The molluscan species show slightly different vertical distributions above and below the formational contact (fig. 11). The sphenodiscids, mostly fragments, occur as low as 2 cm below the contact, at the contact, and as high as 4.5 cm above the contact. The baculites occur as low as 16 cm below the contact, mostly at the contact, and as high as 4.5 cm above the contact. The discoscaphites occur as low as 18 cm below the contact, at the contact, but not above the contact. *Eutrepoceras dekayi* occurs as low as 8 cm below the contact, mostly at the contact, and as high as 6 cm above the contact. *Cucullaea vulgaris* occurs as low as 17 cm below the con-

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loc. R6234D, upper part of the New Egypt Formation, 5–10 cm below the base of the Hornerstown Formation, Parkers Creek, northwest of Eatontown. **D, E, J–L.** USGS Paleobotan. loc. R6234C, upper part of the New Egypt Formation, 0–5 cm below the base of the Hornerstown Formation, Parkers Creek, northwest of Eatontown. **A, B.** *Turnhosphaera hypoflata* (Yun, 1981) Slimani, 1994. **C.** *Piercites pentagonum* (May, 1980) Habib & Drugg, 1987. **D.** *Alisogymnium/Dinogymnium* sp. **E.** *Kleithriasphaeridium truncatum* (Benson, 1976) Stover & Evitt, 1978. **F.** *Palynodinium grallator* Gocht, 1970. **G.** *Thalassiphora pelagica* (Eisenack, 1954) Eisenack & Gocht, 1960. **H, I.** *Deflandrea galatea* (Lejeune-Carpentier, 1942) Lentin & Williams, 1973. **J–L.** *Disphaerogena carposphaeropsis* Wetzel, 1933.

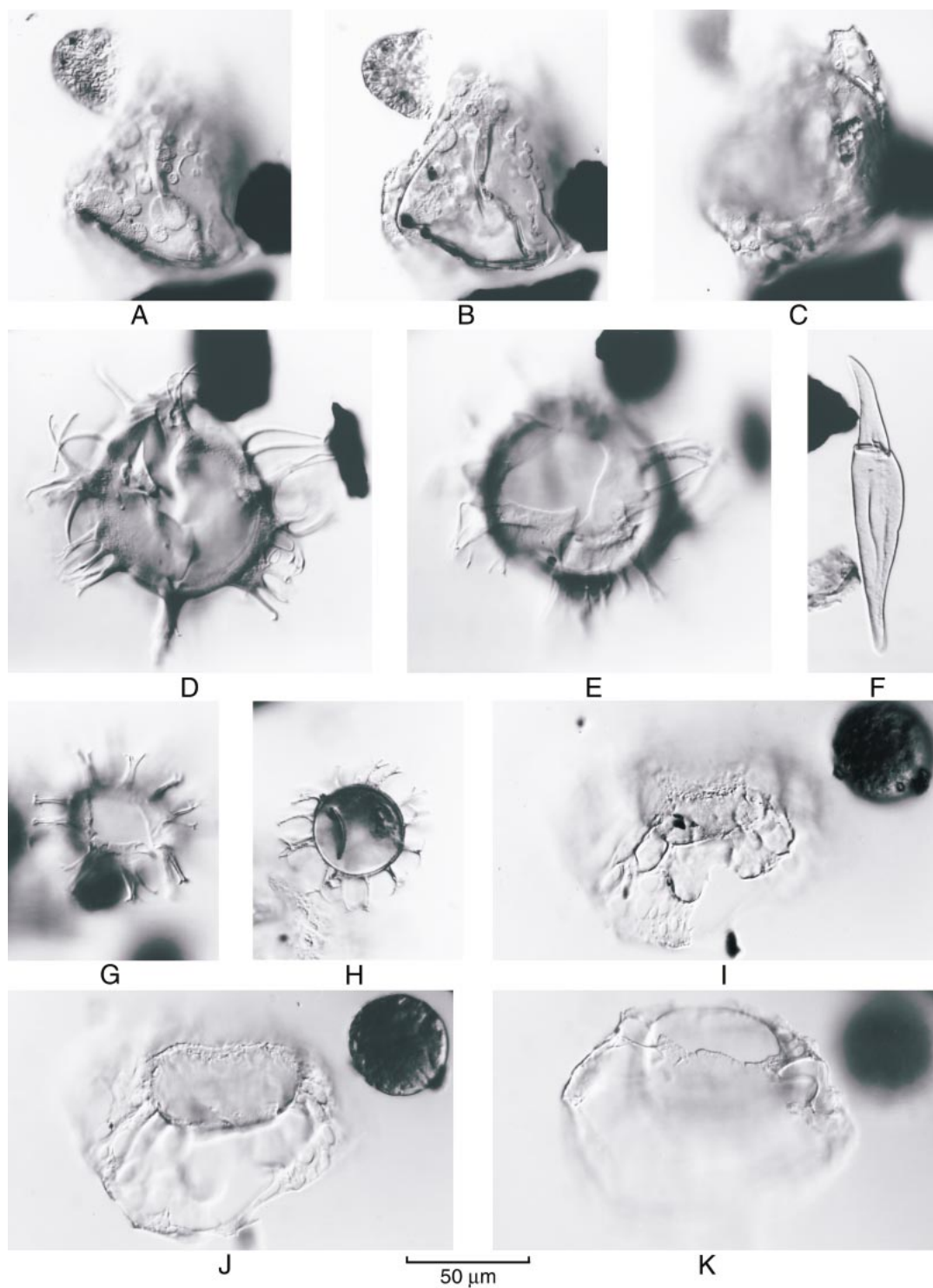


Fig. 8. Dinoflagellates from USGS Paleobotan. loc. R6234, upper part of the New Egypt Formation and lower part of the Hornerstown Formation, Parkers Creek, 0.3 km east of Rt. 35, northwest of

tact, at the contact, and as high as 13 cm above the contact.

Some of the discoscaphites in the top of the New Egypt Formation occur in clusters. One cluster consists of 68 specimens (AMNH 47321–47361, 47364, 47380–1, –2, –3, 47381–47396, 47402, 51057–51059, and 51061–51063) and occurs at approximately 13–18 cm below the contact. Of the 68 specimens, 2 are nearly complete, 47 are fragments of body chambers, 4 are pieces of phragmocones, and 16 are chunks of matrix with scaphite impressions. Of this total, 28 specimens are identified as *Discoscaphites iris* whereas the rest are considered *Discoscaphites* spp., mostly because they are too fragmentary for specific identification. It is difficult to assess the actual number of adults in the cluster because some pieces may fit together in theory, but this is not evident in practice. A minimum estimate is 20 adults, represented by those specimens complete enough to identify the dimorph. A maximum estimate is more than double that (49 adults), represented by all specimens with body chamber fragments. The actual number is probably midway between these two estimates (35), assuming that some pieces of body chambers fit together and that they all belong to the same species.

Another cluster of discoscaphites consists of five pieces of body chambers, all microconchs of *Discoscaphites iris* (AMNH 47308, 47363, 51055, and MAPS A2060a2 and A2060a3), and occurs 1–3 cm below the contact. Both of these clusters may have originated due to burrowing activities of other organisms after the death of the scaphites or as shell accumulations due to predatory activity.

The dinoflagellates in the top 10 cm of the New Egypt Formation are moderately diverse with good preservation (table 1; figs.

6–9). No single species dominates. The species include *Palynodinium grallator* Gocht, 1970, and *Thalassiphora palagica*. A specimen of *Manumiella seelandica* (Lange, 1969) Bujak & Davies, 1983, is preserved with pockmarked damage. This type of preservation suggests melting based on similarly preserved dinocysts presumed to have melted in the Chesapeake meteorite impact (Edwards and Powars, 2003). Alternatively, it may be the result of fungal degradation.

The basal 10 cm of the Hornerstown Formation at AMNH loc. 3345 include a mixture of Maastrichtian and Paleocene dinoflagellates (table 1, figs. 6–9). Maastrichtian species include *Palynodinium grallator*. The diversity of Paleocene dinoflagellates is moderately low. No single species dominates. Paleocene species include *Carpateella cornuta* Grigorovich, 1969, *Fibrocysta/Damassadinium* intergrades, and *Senoniasphaera inornata* (Drugg, 1970) Stover & Evitt, 1978.

LITHOSTRATIGRAPHIC RELATIONSHIPS

In northeastern Monmouth County, the Hornerstown Formation is traditionally portrayed as resting on the Tinton Formation (fig. 2). At our sites, however, the Hornerstown Formation overlies the New Egypt Formation, which in turn overlies the Tinton Formation (fig. 5). The presence of the New Egypt Formation in northeastern Monmouth County indicates that a tongue of this formation protrudes into this area. This supports the interpretative fence diagram of Olsson (1963: fig. 4), although the New Egypt Formation extends much farther northeast than Olsson supposed.

The New Egypt Formation apparently decreases in thickness to the northwest. At AMNH locs. 3345 and 3346, the New Egypt

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Eatontown, northeastern Monmouth County, New Jersey. **A–C, G.** R6234D, 5–10 cm below the base of the Hornerstown Formation. **D–F.** R6234C, 0–5 cm below the base of the Hornerstown Formation. **I–K.** R6234A, 0–5 cm above the base of the Hornerstown Formation. **H.** R6234B, 5–10 cm above the base of the Hornerstown Formation. **A–C.** *Manumiella seelandica* (Lange, 1969) Bujak & Davies, 1983, with pockmarked damage. **D, E.** *Fibrocysta/Damassadinium* intergrades. **F.** *Yolkinigymnium elongatum* (May, 1977) Lentin & Vozzhennikova, 1990. **G.** *Pervosphaeridium tubuloaculeatum* Slimani, 1994. **H.** *Hafniasphaera* sp. **I–K.** *Glaphyrocysta expansa* (Corradini, 1973) Roncaglia & Corradini, 1997.

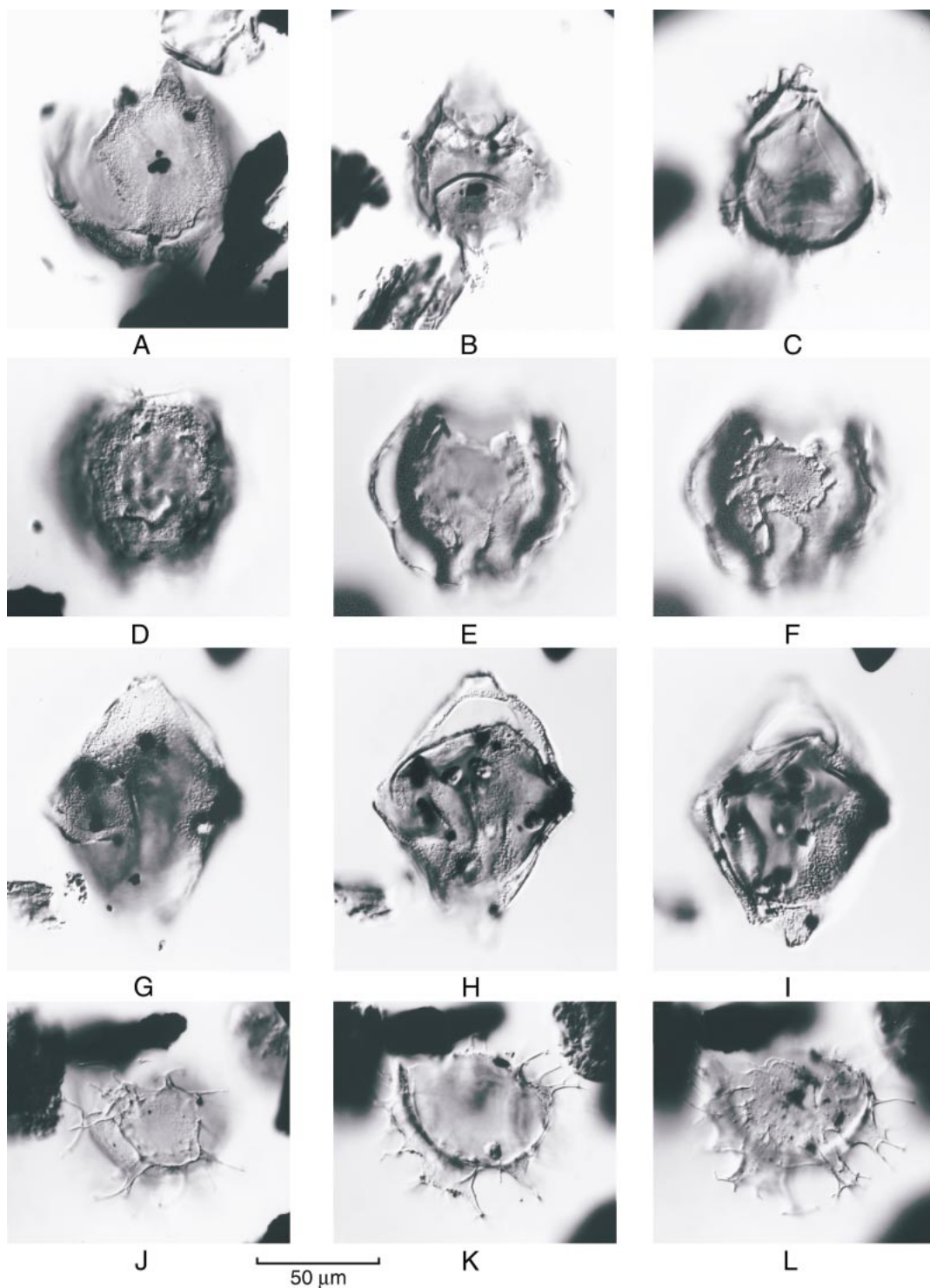


Fig. 9. Dinoflagellates from USGS Paleobotan. loc. R6234, lower part of the Hornerstown Formation, Parkers Creek, 0.3 km east of Rt. 35, northwest of Eatontown, northeastern Monmouth County,

Formation is approximately 6.5 m thick, whereas in Hockhockson Brook (AMNH locs. 3349 and 3350), it is approximately 5 m thick.

There are several exposures in northeastern Monmouth County in which the Hornerstown Formation has been reported as overlying the Tinton Formation (e.g., Beers Hill, Holmdel Road, 0.8 km north of Crawford Corner [Weller, 1907: loc. 110; Olsson, 1963: loc. NJK120; Gallagher, 1993: 140]; pits on either side of Rt. 36 just east of Atlantic Highlands [Minard et al., 1969]; and exposures on the bluffs along the north side of the Navesink River west of Sea Bright [Minard et al., 1969]). Most of these exposures are very weathered or no longer accessible. In the Manasquan River Drainage, central Monmouth County (approximately 100 ft above sea level), the Hornerstown Formation unconformably overlies the Tinton Formation (Landman et al., in prep. a). The implication is that in downdip sections, the Hornerstown Formation overlies the New Egypt Formation, whereas in updip sections, the New Egypt Formation disappears altogether, leaving the Hornerstown Formation resting directly on the Tinton Formation.

Both the New Egypt and Hornerstown Formations are mostly composed of glauconitic minerals. However, the glaucony is slightly different in the two formations. In the New Egypt Formation, the glauconitic grains are very dark green or yellowish brown whereas in the Hornerstown Formation, they are dusky green. In addition, the New Egypt Formation contains more mica and quartz than the Hornerstown Formation, although the siliciclastic component is low in both units. These differences suggest a change in the environment of deposition. This interpretation is consistent with the decrease in total carbon as well as organic carbon in passing from the New Egypt into the Hornerstown Formation. This decrease may

reflect changes in the productivity and rate of sedimentation in the two environments or differences in the diagenetic history since deposition.

MOLLUSCAN BIOSTRATIGRAPHY

The lowest occurrence of ammonites in the study area is in the Tinton Formation, which yields nearly complete specimens of *Sphenodiscus lobatus*. Elsewhere in New Jersey, this species is known from the top of the Tinton Formation near Freehold, central Monmouth County (Landman et al., in prep. a), the upper part of the Navesink Formation and the lower part of the New Egypt Formation, southwestern Monmouth county (Landman et al., in prep. b), and the base of the Hornerstown Formation, Gloucester County (Gallagher, 1993; Kennedy et al., 1995; Kennedy and Cobban, 1996). This species also occurs in other parts of the Atlantic Coastal Plain (Kennedy et al., 1997; Landman et al., 2004), the Gulf Coastal Plain (Kennedy and Cobban, 1993; Cobban and Kennedy, 1995; Kennedy et al., 1997), Trans-Pecos Texas and northern Mexico (Stephenson, 1941, 1955), and the Western Interior (Landman and Waage, 1993; Kennedy et al., 1998). It is generally interpreted as late Maastrichtian in age (Kennedy et al., 1997).

The assemblage of *Discoscaphites minardi*, *Discoscaphites* sp., and *Eubaculites carinatus* in the upper part of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation at AMNH locs. 3346 and 3347 represents the *D. minardi* Zone. The associated bivalves and gastropods are listed in table 2 and include *Cucullaea neglecta* Gabb, 1861. The *D. minardi* Zone has not been reported elsewhere in New Jersey but is present in the Severn Formation in Kent County, Maryland (Landman et al., 2004). This zone represents the middle

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New Jersey. **A, G–I.** R6234A, 0–5 cm above the base of the Hornerstown Formation. **B–F, J–L.** R6234B, 5–10 cm above the base of the Hornerstown Formation. **A.** *Carpatella cornuta* Grigorovich, 1969. **B, C.** *Fibrocysta/Damassadinium* intergrades. **D–F.** *Senoniasphaera inornata* (Drugg, 1970) Stover & Evitt, 1978. **G–I.** *Manumiella seelandica* (Lange, 1969) Bujak & Davies, 1983. **J–L.** *Palynodinium grallator* Gocht, 1970, reworked.

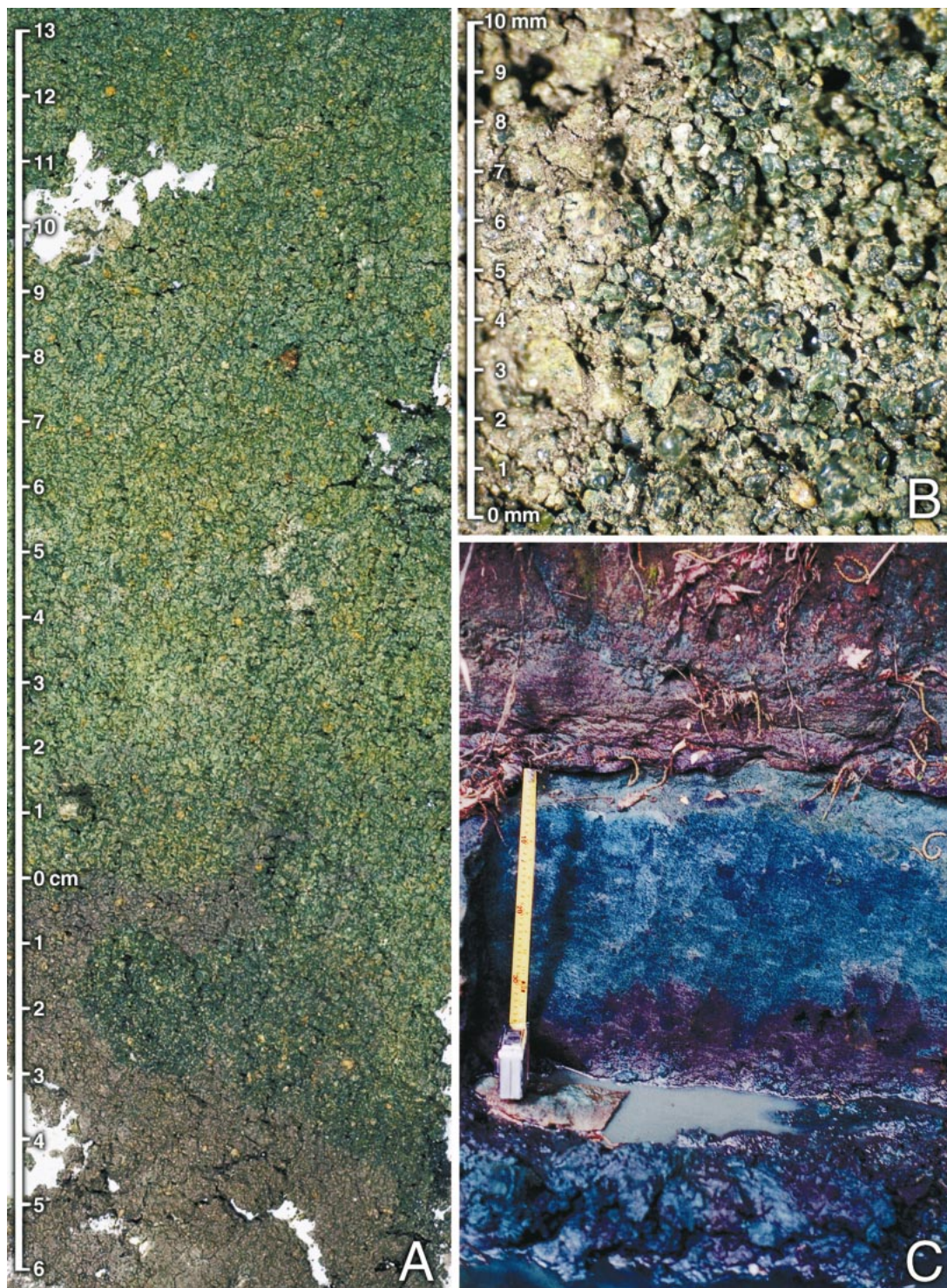


Fig. 10. Formational contact between the New Egypt and Hornerstown Formations at AMNH loc. 3345, Parkers Creek, northeastern Monmouth County, New Jersey. A. Close-up of contact (0 cm) pre-

part of the upper Maastrichtian, corresponding to the upper part of calcareous nannofossil Subzone CC26a and the lower part of Subzone CC26b.

The assemblage of fossils containing *Discoscaphites iris* in the upper 20 cm of the New Egypt Formation at AMNH loc. 3345 indicates the *D. iris* Zone. This zone may actually be thicker but the rest of the formation is not exposed at this locality. In addition to *D. iris*, the other ammonites are *Eubaculites carinatus*, *E. latecarinatus*, and *Sphenodiscus pleurisepta*. The *D. iris* Zone is the highest ammonite zone in North America (Landman et al., 2004). Elsewhere on the Gulf and Atlantic Coastal Plains it occurs immediately below the Cretaceous/Tertiary boundary. The *D. iris* Zone corresponds to the upper part of calcareous nannofossil Subzone CC26b.

Fossils from the *D. iris* Zone occur up to 13 cm above the formational contact, indicating reworking. These fossils are preserved as internal molds with New Egypt Formation lithology. They are surrounded, however, by sediments of the Hornerstown Formation.

Cucullea vulgaris is present in the top 20 cm of the New Egypt Formation and as reworked material at the base of the Hornerstown Formation. This species has traditionally been considered an index fossil for the Hornerstown Formation but actually is derived from the upper part of the New Egypt Formation.

DINOFLAGELLATE BIOSTRATIGRAPHY

BACKGROUND

To evaluate the biostratigraphic significance of the Cretaceous dinoflagellates in our samples, we relied on the biostratigraphic zonation established by Firth (1987) and Edwards et al. (1999) for the Atlantic Coastal Plain. The Santee Coastal Reserve (SCR) core from Charleston County, South Carolina, includes the Maastrichtian Pee Dee For-

mation and contains nannofossils and dinoflagellates, permitting a correlation between the two fossil groups (Edwards et al., 1999). The core is also calibrated with strontium isotope- and magnetostratigraphy. By regressing the age-calibrated paleomagnetic data and the ranges of calcareous nannofossils against depth in the SCR core, Edwards et al. (1999: fig. 11; reprinted with modification as fig. 13) calculated numerical ages for key dinoflagellate datums.

Landman et al. (2004) reviewed the use of the SCR core for correlating Upper Cretaceous sections on the Atlantic Coastal Plain. The occurrences of key dinoflagellate species in the Cretaceous part of the SCR core are listed below starting from the top downward (Edwards et al., 1999: fig. 5):

- Lowest occurrence of *Palynodinium grallator* (370.3 ft in SCR core)
- Lowest occurrence of *Disphaerogena carposphaeropsis* (389.3 ft in SCR core)
- Lowest occurrence of *Thalassiphora pelagica* (390.8 ft in SCR core)
- Highest occurrence of *Isabelidium cooksoniae* (436.4 ft in SCR core)
- Lowest occurrence of *Deflandrea galatea* (436.4 ft in SCR core)
- Highest occurrence of *Alterbidinium acutulum* (474.2 ft in SCR core)

Based on studies of dinoflagellates from the North Sea (Schiøler and Wilson, 1993), the lowest occurrence of *Palynodinium grallator* defines the base of the *P. grallator* Zone, which is the uppermost Maastrichtian dinoflagellate zone. The *P. grallator* Zone in the North Sea is divided into two subzones based on the lowest occurrence of *Thalassiphora pelagica* partway through the zone. Because the lowest occurrence of *T. pelagica* in the SCR core is below that of *P. grallator*, this distinction cannot reliably be made in the United States. Therefore, if *P. grallator* is present in our samples, we state uppermost Maastrichtian *P. grallator* Zone. If *P. grallator* is absent, but *T. pelagica* is present, we state upper, but probably not uppermost

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served in a peel. **B.** Overview of contact showing the high degree of bioturbation. The red marks on the tape indicate 10 cm intervals. **C.** Close-up of a burrow (preserved in the peel) in the top of the New Egypt Formation filled with large glauconite grains (arrow).

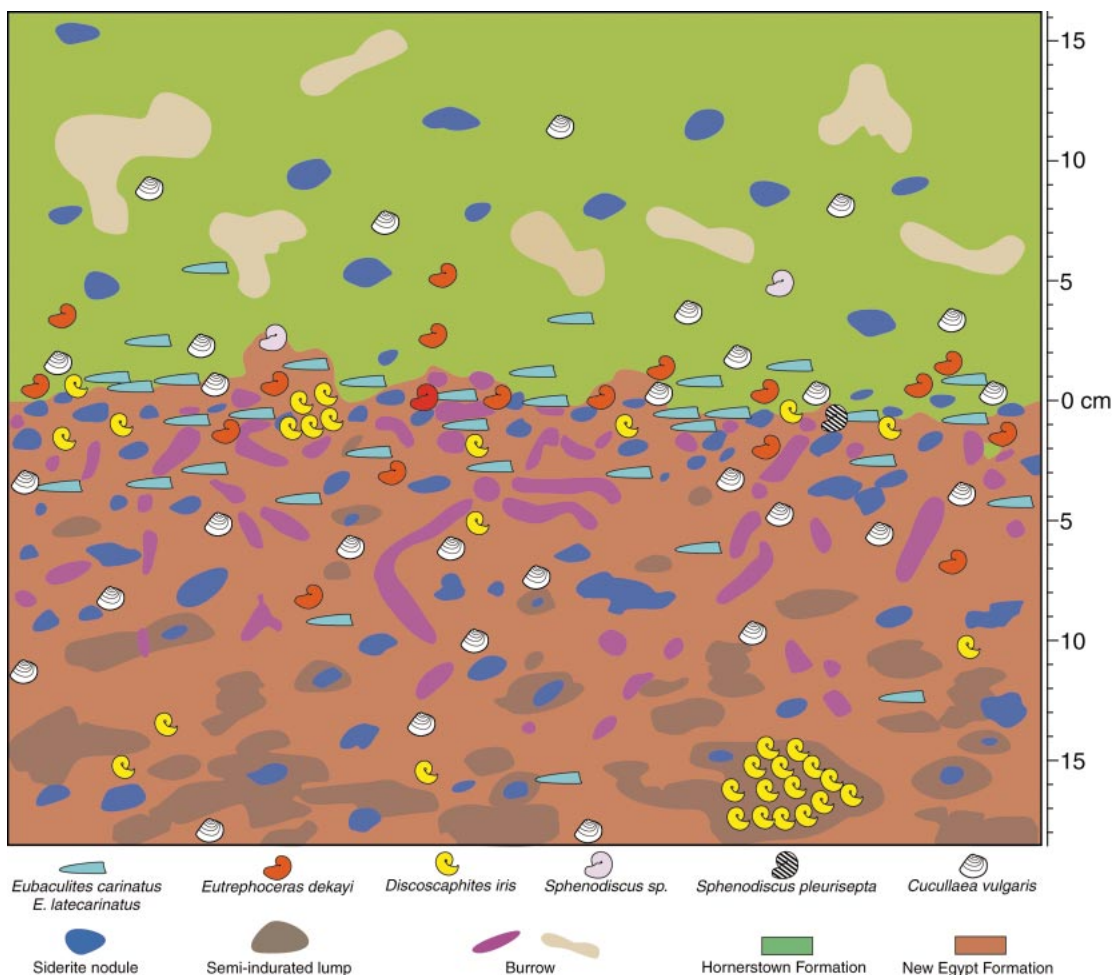


Fig. 11. Diagram of the contact between the New Egypt and Hornerstown Formations at AMNH loc. 3345, Parkers Creek, northeastern Monmouth County, New Jersey, showing the distribution of cephalopods and bivalves. Vertical scale = 35 cm; horizontal scale = 13 m. Not all of the fossils collected are shown nor do the symbols imply that the specimens are whole. The diagram is intended to provide an overview of the distribution of molluscan fossils, documenting that most of them occur at the formational contact.

Maastrichtian. The *P. grallator* Zone approximately correlates with the upper part of calcareous nannofossil Subzone CC26b.

Nannofossil workers cite the base of calcareous nannofossil Subzone CC25b, which is close to, but not exactly coincident with, the highest occurrence of the dinocyst *Alterbidinium acutulum*, to mark the base of the upper Maastrichtian. *Alterbidinium acutulum* is absent in our stratigraphically lowest samples, but *Deflandrea galatea* is present. The

lowest occurrence of *D. galatea* in the SCR core is well above the base of calcareous nannofossil Subzone CC25b. Thus, the presence of *D. galatea* in these samples indicates that they are upper Maastrichtian. The occurrence of *Isabelidinium cooksoniae sensu lato* further indicates that they are lower upper Maastrichtian. This interpretation agrees with dinoflagellate data from the ENCI quarry in the Netherlands, where Schiøler et al. (1997) placed their entire section in the upper

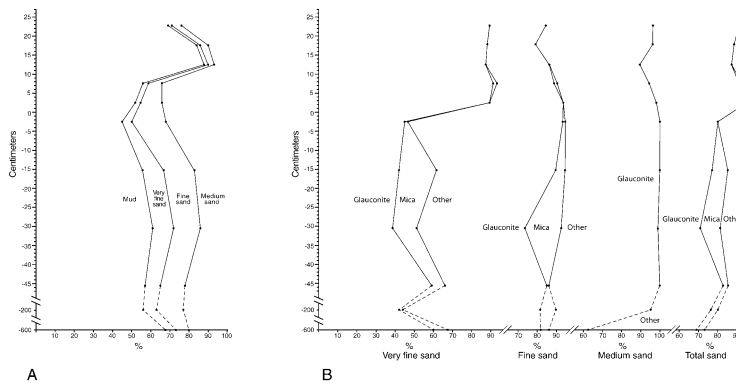


Fig. 12. **A.** Grain size analysis of the composite section at AMNH locs. 3345, 3346, and 3349, northeastern Monmouth County, New Jersey. The New Egypt/Hornerstown formational contact is plotted at 0. The percentage is by weight. **B.** Mineralogy of the same samples as percentage of grains of glauconite, mica, and other (e.g., quartz, heavy minerals).

Maastrichtian *Lithraphidites quadratus* (Zone CC25) and *Nephrolithus frequens* (Zone CC26) calcareous nannofossil zones.

Evaluation of the Paleocene dinoflagellate biostratigraphy relies on interpretations of the ranges of *Senoniasphaera inornata*, *Carpatella cornuta*, and *Tectatodinium rugulatum* Hansen (1977). The ranges of these three species have been documented in numerous Cretaceous/Tertiary sections around the world including New Jersey (Olsson et al., 1997, 2002), Alabama (Habib et al., 1996), Georgia (Firth, 1987, 1993), the western North Atlantic (Habib and Drugg, 1987), the Danish Basin (Hansen, 1977, 1979; Hultberg, 1986; Brinkhuis et al., 1998), the Carpathians (Grigorovich, 1969), northern Germany (Stover and Evitt, 1978), and Tunisia (Brinkhuis et al., 1998).

Hansen (1977) recognized the biostratigraphic significance of these species in the Danish Basin and defined the *Damassadinium californicum* (= *Danea mutabilis*) Zone, which is approximately equivalent to the entire Danian. He divided this zone into the lower *Senoniasphaera inornata* (= *Chiropteridium inornatum*) Subzone and the upper *Hafniasphaera cryptovesiculata* Subzone. He further subdivided the *S. inornata* Subzone into three zonules: in ascending stratigraphic order, the *Carpatella cornuta* Zonule, the *Tectatodinium rugulatum* (= *Xenicodinium rugulatum*) Zonule, and the *Xenicodinium lubricum* Zonule. This bio-

stratigraphic zonation has since been modified by Hultberg (1986, fig. 6).

OCCURRENCES OF DINOFLAGELLATES

We describe below the occurrences of dinoflagellates at each of our localities and discuss the biostratigraphic significance (table 1; figs. 6–9, 14).

- AMNH 3348 (R6234H), Tinton Formation, Hochhockson Brook, near Tinton Falls, Monmouth County, New Jersey.

Species include *Deflandrea galatea* and *Isabelidinium cooksoniae sensu lato*. By comparison with the reported occurrences of these species in the SCR core, this sample represents the lower part of the upper Maastrichtian. It is approximately correlative with material from 436.4 ft in the SCR core, which coincides with calcareous nannofossil Zone CC25b (Edwards et al., 1999). *Trithyroidinium striatum* Benson, 1976, is also present. This species is better known from older material, but has been reported in the lower part of the upper Maastrichtian in the Netherlands (Schjølter et al., 1997). Campanian forms are conspicuous in their absence. By comparison with the SCR core, this sample is 68.2–67.4 Ma.

- AMNH loc. 3349 (R6234G), upper part of the Tinton Formation and lower part of the New Egypt Formation, Hockockson Brook, 0.5 km southwest of the intersection of Water

TABLE 2

**Invertebrate Fossils at AMNH Locality 3346,
Upper New Egypt Formation, 1.5–2.0 m Below
the Base of the Hornerstown Formation,
Parkers Creek, Northeastern Monmouth County,
New Jersey**

CEPHALOPODA

- Discoscaphites minardi* Landman et al., 2004
- Discoscaphites* sp.
- Eubaculites carinatus* (Morton, 1834)
- Eubaculites* sp.
- Sphenodiscus* sp.
- Eutrephoceras dekayi* (Morton, 1834)

PELECYPODA

- Pyncnodonte convexa* (Say, 1820)
- Exogyra costata* Say, 1820
- Agerostrea nasuta* (Morton, 1834)
- Cucullaea neglecta* Gabb, 1861
- Panope decisa* Conrad, 1853
- Veniella conradi* Morton, 1833
- Chlamys venustus* Morton, 1833
- Gastrochaena whitfieldi* Weller, 1907
- Xylophagella irregularis* (Gabb, 1860)

GASTROPODA

- Gyrodes* sp.
- Turritella* sp.
- Pyropsis* sp.
- Arrhoges lobata* (Wade, 1926)
- numerous unidentified snails

ARTHROPODA

- Protocallianassa mortoni* (Pilsbry, 1901)
- Hoploparia gabbi* Pilsbry, 1901
- two unidentified crabs

PORIFERA

- Cliona microtuberum* Stephenson, 1941

TABLE 3

**Invertebrate Fossils at AMNH Locality 3345,
Uppermost 20 cm of the New Egypt Formation
and Basal 15 cm of the Hornerstown Formation,
Parkers Creek, Northeastern Monmouth County,
New Jersey**

CEPHALOPODA

- Discoscaphites iris* (Conrad, 1858)
- Discoscaphites minardi* Landman et al., 2004
- Discoscaphites gulosus* (Morton, 1834)
- Discoscaphites* spp.
- Eubaculites carinatus* (Morton, 1834)
- Eubaculites latecarinatus* (Brunnschweiler, 1966)
- Sphenodiscus pleurisepta* (Conrad, 1857)
- Sphenodiscus* spp.
- Eutrephoceras dekayi* (Morton, 1834)

PELECYPODA

- Cucullaea vulgaris* Morton, 1830
- Pyncnodonte convexa* (Say, 1820)
- Crassatella vadosa* Morton, 1834
- Postigata crenata* Wade, 1926
- Solyma lineolatus* Conrad, 1870
- Gervilliopsis ensiformis* (Conrad, 1858)
- Pinna laqueata* Conrad, 1858
- Lithophaga carolinensis* (Conrad, 1875)

GASTROPODA

- Xenophora leprosa* (Morton, 1834)
- Gyrodes* sp.
- Turritella* sp.
- Pyropsis* sp.
- Euspira* sp.

ARTHROPODA

- Protocallianassa mortoni* (Pilsbry, 1901)

PORIFERA

- Cliona microtuberum* Stephenson, 1941

Street and Tinton Avenue, Monmouth County, New Jersey.

Species include *Deflandrea galatea* and *Thalassiphora pelagica*. However, *Disphaerogena carposphaeropsis* Wetzel, 1933, and *Palynodinium grallator* are absent, suggesting that this sample is upper, but not uppermost Maastrichtian. It is approximately correlative with material from 390.8 ft in the SCR core, which lies within the *Nephrolithus frequens* calcareous nannofossil Zone spanning the upper part of Subzone CC26a and the lower part of Subzone CC26b (Edwards et al., 1999). By comparison with the SCR core, this sample is 66.4–66.0 Ma.

- AMNH loc. 3346 (R6234E), New Egypt For-

mation, approximately 1.5–2 m below the base of the Hornerstown Formation, Parkers Creek, 0.1 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

Similar to the sample from the upper part of the Tinton Formation and lower part of the New Egypt Formation at AMNH loc. 3349, the dinoflagellates from this site include *Deflandrea galatea* and *Thalassiphora pelagica*. *Disphaerogena carposphaeropsis* and *Palynodinium grallator* are absent, implying that this sample is upper, but not uppermost Maastrichtian. It is approximately correlative with material from 390.8 ft in the SCR core, which lies within the *Nephrolithus frequens* calcareous nannofossil Zone span-

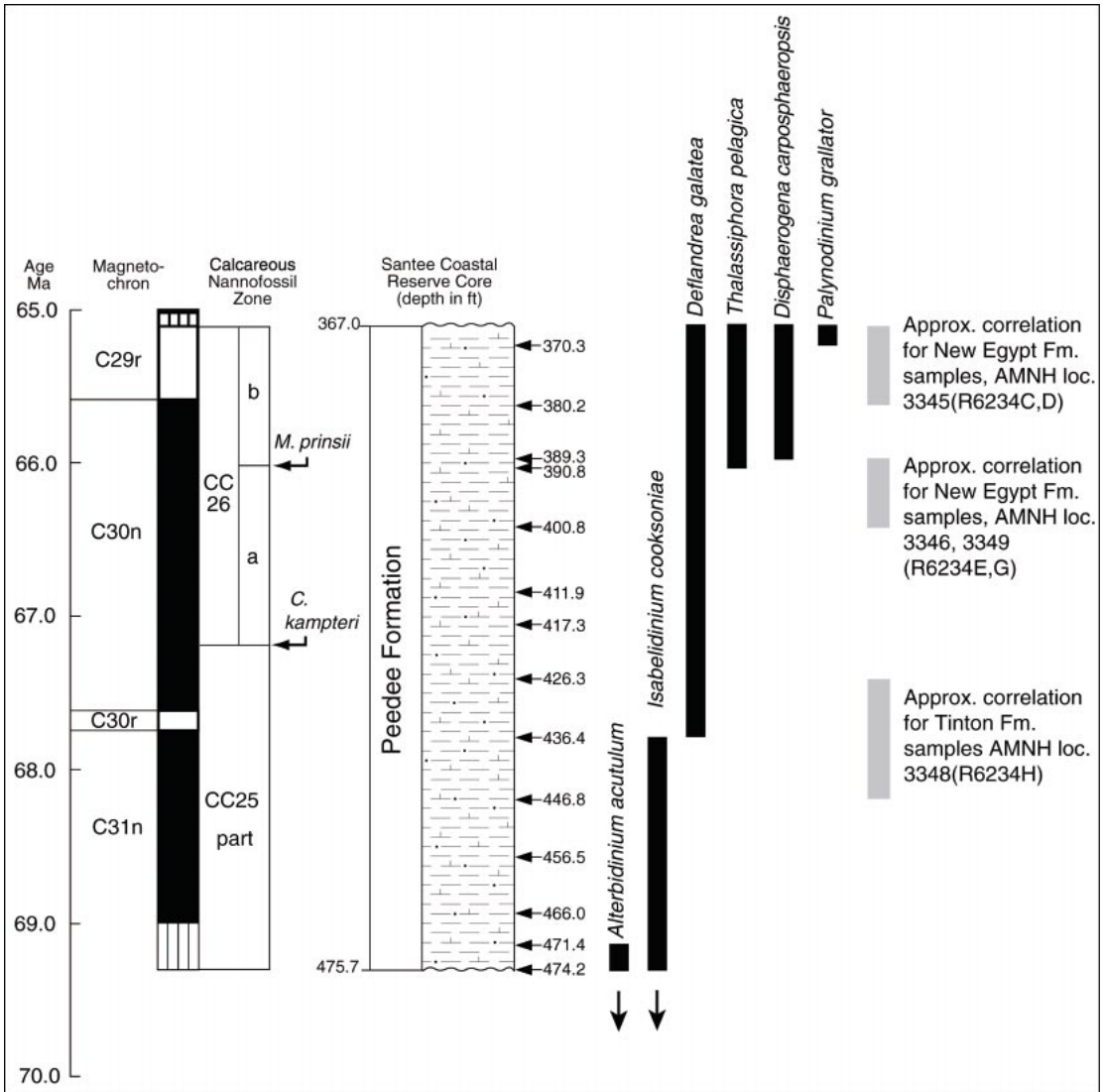


Fig. 14. Correlation of the samples from northeastern Monmouth County, New Jersey, with the Santee Coastal Reserve (SCR) core based on the distribution of dinoflagellates. The magnetochron below 468 ft is indeterminate.

The dinoflagellates include *Palynodinium grillator* and *Thalassiphora pelagica*. These species represent the uppermost Maastrichtian *P. grillator* Zone, probably the Tpe (*T. pelagica*) Subzone of Schiøler and Wilson (1993), correlative with the upper part of calcareous nannofossil Zone CC26b. By comparison with the SCR core, this sample is 65.6–65.0 Ma. This sample includes a specimen of *Manumiella seelandica* with distinctive pockmarked damage.

- AMNH loc. 3345 (R6234C), New Egypt Formation, 0–5 cm below the base of the Hornerstown Formation, Parkers Creek, 0.3 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

Similar to the sample immediately below, the dinoflagellates include *Palynodinium grillator* and *Thalassiphora pelagica*, indicating the uppermost Maastrichtian *P. grillator* Zone, probably the Tpe Subzone of Schiøler and Wilson (1993), correlative with

the upper part of calcareous nannofossil Zone CC26b. None of the specimens recorded as “*Fibrocysta/Damassadinium* intergrades” is unquestionably identified as *Damassadinium californicum* (Drugg, 1967) Fensome et al., 1993, which is a marker of the basal Danian, but many are obviously part of the *D. californicum* lineage.

- AMNH loc. 3345 (R6234A), 0–5 cm above the base of the Hornerstown Formation, Parkers Creek, 0.3 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

The most notable species is *Carpatella cornuta*. The lowest occurrence of this species on the Atlantic Coastal Plain is at the base of the Clayton Formation (above an unfossiliferous sandstone bed 2.1 m thick) in the Albany core, Dougherty County, Georgia, where it indicates the lower Danian (Firth, 1987, 1993). On the Gulf Coastal Plain, this species occurs in calcareous nannofossil Zone NP1 in the basal beds of the Clayton Formation at three sites in south-central Alabama (Braggs, Mussel Creek, and a well near Braggs), where it also indicates the basal Danian (Moshkovitz and Habib, 1993). The lowest occurrence of *C. cornuta* at Miller’s Ferry, Alabama, is 1.23 m above the K/T boundary in the lower half of foraminiferal Zone P α ; it ranges upward into foraminiferal Zone Pla (Habib et al., 1996). The lowest occurrence of this species at Moscow Landing, Alabama, is 1.69 m above the base of the Clayton Formation; this horizon correlates with calcareous nannofossil Zone NP1 and the middle part of foraminiferal Zone P α (Habib et al., 1996).

Elsewhere, *Carpatella cornuta* occurs in Denmark in the *C. cornuta* Zonule in the lower part of the Danian (Hansen, 1977). The lowest occurrence of *C. cf. cornuta* (with a spongy thick outer wall) is in foraminiferal Zone PO? at Stevns Klint, Denmark, and the lowest occurrence of more typical representatives of this species at Stevns Klint is in foraminiferal Zone Plc? (Brinkhuis et al., 1998: fig. 4). The lowest occurrence of this species at El Kef, Tunisia, is in the upper half of foraminiferal Zone PO (Brinkhuis et al., 1998: fig. 2). Williams et al. (2004), in their global survey of dinoflagellate biostratigra-

phy, recorded the range of *C. cornuta* as 64.75–59.95 Ma in northern midlatitudes and 64.75–60? Ma in northern low latitudes.

The absence of *Tectatodinium rugulatum* in our sample suggests that it is below the *T. rugulatum* Zone of Hansen (1977). The lowest occurrence of *T. rugulatum* is just below the base of calcareous nannofossil Zone NP2 (Stover et al., 1996: text-fig. 31), which approximately corresponds to the base of foraminiferal Zone Plb, according to Berggren et al. (1995: fig. 1).

Reworked material in our sample includes uppermost Maastrichtian *Palynodinium grallator* and *Rugubivesiculites* sp. pollen. None of the specimens recorded as “*Fibrocysta/Damassadinium* intergrades” is unquestionably identified as *Damassadinium californicum*, but many are obviously part of the *D. californicum* lineage.

- AMNH loc. 3345 (R6234B), 5–10 cm above the base of the Hornerstown Formation, Parkers Creek, 0.3 km east of Rt. 35, northwest of Eatontown, Monmouth County, New Jersey.

In addition to questionable specimens of *Carpatella cornuta*, this sample also contains *Senoniasphaera inornata*, which is not present in the underlying sample and, thus, is presumably not reworked. The lowest occurrence of *S. inornata* in the Bass River borehole, New Jersey, is immediately above the spherule layer in foraminiferal Zone PO (Olsson et al., 1997, 2002). The lowest occurrence of this species in the Albany core, Georgia, is at the base of the Clayton Formation (Firth, 1987, 1993). The lowest occurrence of this species at Mussel Creek, Alabama, is 25 cm above the base of the Clayton Formation (Moshkovitz and Habib, 1993), which according to the biostratigraphy of Olsson and Liu (1993), approximately corresponds to foraminiferal Zone PO. At Braggs, Alabama, *S. inornata* ranges from the base of calcareous nannofossil Zone NP1 to the lower part of Zone NP2 (Moshkovitz and Habib, 1993: fig. 7). At Miller’s Ferry, Alabama, *S. inornata* ranges from foraminiferal Zone PO to Pla (Habib et al., 1996: fig. 2). The lowest occurrence of *S. inornata* at Moscow Landing, Alabama, is 81 cm above

the base of the Clayton Formation in foraminiferal Zone PO (Habib et al., 1996).

As previously noted, Hansen (1977, 1979) recorded *Senoniasphaera inornata* from the Danish Basin and defined the *S. inornata* Subzone as the lower of two subzones comprising the *Damassadinium californicum* Zone. The range of *S. inornata* extends slightly into the overlying Subzone of *Hafniasphaera cryptovesiculata*. According to Hansen (1977, 1979), *S. inornata* also ranges into the uppermost Maastrichtian *T. pelagica* Subzone of the *P. grallator* Zone, but this conclusion was probably based on a misidentification (Hultberg and Malmgren, 1985; Hultberg, 1986; Schiøler and Wilson, 1993).

Elsewhere, the lowest occurrence of *Senoniasphaera inornata* is in the middle of foraminiferal Zone PO at El Kef, Tunisia, in the lower part of foraminiferal Zone PO at Barranco del Gredero, near Caravaca, Spain, and in the middle of foraminiferal Zone PO? at Stevns Klint, Denmark (Brinkhuis et al., 1998: figs. 2–4). Brinkhuis et al. (2003) reported this species in samples from the K/T boundary on the East Tasman Plateau, where it also occurs below the K/T boundary, a fact that these authors attributed to downward reworking. Williams et al. (2004) recorded the range of *S. inornata* as 64.95–62.6 Ma in northern midlatitudes, 64.95–62? Ma in northern low latitudes, and 64.7–63? Ma in southern high latitudes.

The absence of *Tectatodinium rugulatum* in our sample suggests that it is below the *T. rugulatum* Zone. The lowest occurrence of this species is just below the base of calcareous nannofossil Zone NP2 (Stover et al., 1996: text-fig. 31), which approximately corresponds to the base of foraminiferal Zone Plb (Berggren et al., 1995: fig. 1). However, the moderately low diversity of our sample means that this interpretation must be qualified.

Reworked material includes uppermost Maastrichtian *Palynodinium grallator* and *Rugubivesiculites* sp. pollen. None of the specimens recorded as “*Fibrocysta/Damassadinium* intergrades” is unquestionably identified as *Damassadinium californicum*, but many are obviously part of the *D. californicum* lineage.

BIOSTRATIGRAPHIC SYNTHESIS

The dinoflagellate and molluscan data imply the following biostratigraphic relationships.

1. The presence of *Deflandrea galatea* and *Isabelidinium cooksoniae sensu lato* in the Tinton Formation, in association with *Sphenodiscus lobatus*, indicates calcareous nannofossil Subzone CC25b. This approximately correlates with the *Discoscaphites conradi* Assemblage Zone (Landman et al., 2004). Elsewhere in New Jersey, this zone is present in the upper part of the Navesink Formation and lower part of the New Egypt Formation in the Crosswicks Creek Basin, southwestern Monmouth County (Landman et al., in prep. b).

2. The beds extending from the lower part of the New Egypt Formation to approximately 1.5–2 m below the base of the Hornerstown Formation contain *Deflandrea galatea* and *Thalassiphora pelagica* and correspond to the *Nephrolithus frequens* calcareous nannofossil Zone (upper part of calcareous nannofossil Subzone CC26a and lower part of Subzone CC26b). The upper part of this section contains *Discoscaphites minardi*, indicating the *D. minardi* Assemblage Zone.

3. The beds in the uppermost 20 cm of the New Egypt Formation contain *Palynodinium grallator* and *Thalassiphora pelagica*, indicating the *P. grallator* Zone, probably the Tpe Subzone, corresponding to the upper part of calcareous nannofossil Subzone CC26b. These beds also yield *Discoscaphites iris* indicating the *D. iris* Assemblage Zone. Elsewhere in New Jersey, the *D. iris* Zone occurs at the top of the New Egypt Formation (and as reworked material at the base of the Hornerstown Formation) in the Crosswicks Creek Drainage, southwestern Monmouth County (Landman et al., in prep. b), and at the top of the Tinton Formation (and as reworked material at the base of the Hornerstown Formation) in the Manasquan River Drainage, central Monmouth County (Landman et al., in prep. a). *Discoscaphites iris* is absent at the Inversand Pit, Gloucester County, although other species representative of this zone are present (Kennedy and Cobban, 1996).

4. The basal 5 cm of the Hornerstown Formation at Parkers Creek contain *Carpateella cornuta* as well as reworked Maastrichtian ammonites, nautilids, bivalves, gastropods, and dinoflagellates. The overlying 5 cm additionally contain *Senoniasphaera inornata*. Based on published studies, *C. cornuta* and *S. inornata* occur in foraminiferal Zones PO–Pla. The absence of *Tectatodinium rugulatum* in our samples lends further support to this interpretation. Within this biostratigraphic interval, we are inclined to assign our samples to Zones PO–P α , which correlates with the lowest occurrences of *C. cornuta* and *S. inornata* on the Gulf and Atlantic Coastal Plains. This assignment is also consistent with the position of the upper boundary of the Navesink Sequence in New Jersey (called the Navesink II Sequence by Miller et al. [2004]). Olsson et al. (2002: fig. 3) placed the upper boundary of the Navesink Sequence between foraminiferal zones Pla and Plc; Zone Plb is missing at the Bass River borehole. This sequence boundary is 1.5–2 m above the base of the Hornerstown Formation in the Crosswicks Creek Drainage (although this relationship has not been observed in the same outcrop). This implies that the base of the Hornerstown Formation in this area, and, by extension, at Parkers Creek, is well below foraminiferal Zone Pla and probably in Zones PO–P α .

IRIDIUM ANALYSIS

We performed an iridium analysis of eight samples from AMNH loc. 3345. The samples consisted of sediments from 5 cm intervals starting from 15 cm below the formational contact to 25 cm above it. The analysis was performed commercially by XRAL Laboratories, Toronto, Ontario, using NiS fire assay with a detection limit of 0.1 ppb. The concentration of iridium in all eight samples was below the detection limit.

Elsewhere in New Jersey, Gallagher (1992) investigated the presence of iridium in the upper part of the New Egypt Formation and lower part of the Hornerstown Formation at Sewell, Gloucester County. He sampled 10 cm intervals starting from 10 cm below the formational contact to 3 m above it. He defined the K/T boundary at the top

of the Main Fossiliferous Layer (MFL), following the interpretation of Koch and Olsson (1977).

The values of iridium at Sewell are low and less than 0.1 ppb. They are expressed in ppt (parts per trillion; misstated as ppb, parts per billion, in Gallagher, 1993). All of the values are less than 200 ppt and are much lower than iridium concentrations at other K/T boundary sections, which vary from 0.5–60 ppb (Ganapathy et al., 1981; Kiessling and Claeys, 2002). Gallagher (1992) did not detect any anomaly at the horizon he identified as the K/T boundary. The values immediately below and above this horizon are 110 and 40 ppt, respectively. Gallagher detected three peaks of 100–200 ppt at approximately 10 cm below this horizon, 140 cm above it, and 300 cm above it. He concluded that these slightly elevated values could represent the reworking of an originally more enriched, stratigraphically restricted layer due to subsequent bioturbation. Alternatively, he speculated that these peaks could reflect multiple events.

Olsson et al. (2002) reported an iridium concentration of approximately 2.4 ppb just below the spherule bed at the Bass River borehole, Burlington County, New Jersey. They attributed this anomaly to a postdepositional downward diffusion of iridium from an originally enriched layer. An elevated concentration of iridium ($\approx$ 800 ppt) is also present near the top of the Tinton Formation in the Manasquan River Drainage, central Monmouth County (Landman et al., in prep. a).

STRONTIUM ANALYSIS

We investigated the strontium isotopic value of shell material from the New Egypt/Hornerstown formational contact at AMNH loc. 3345. We compared this value to that of shell material from the Owl Creek Formation, Owl Creek, Mississippi, representing the uppermost Maastrichtian *Discoscaphites iris* Zone.

The material from New Jersey consisted of septa from five specimens of *Eubaculites latecarinatus* associated with specimens of *Discoscaphites iris*. The material was scraped off the specimens and sonified to re-

move adhering matrix. Because there was so little material, it was all combined into a single sample. Under the light microscope, the material appeared iridescent with a golden metallic luster, indicative of the mineral bornite. Many of the surfaces exhibited tiny black particles, which were impossible to completely remove. Under scanning electron microscopy (SEM), the shell surfaces appeared weathered. The nacreous microstructure was visible in cross section but many of the nacreous plates were fused together.

For comparison, we analyzed two samples of shell material from the body chambers of each of two specimens of *Discoscaphites iris* from U.S. Geological Survey loc. 25421 from the Owl Creek Formation, Owl Creek, near Ripley, Tippah County, Mississippi. In contrast to the New Jersey material, this material appeared pristine under both light microscopy and SEM.

The samples were analyzed commercially at the MIT TIMS Laboratory, Cambridge, Massachusetts by F.O. Dudas. The values of the two samples from the Owl Creek Formation are identical, with slightly different standard errors: 0.707928 (% SE = 0.0007 and 0.0006). The value of the sample from New Jersey is higher: 0.707973 (% SE = 0.0006).

These high values are consistent with elevated values of $^{87}\text{Sr}/^{86}\text{Sr}$ reported from Cretaceous/Tertiary boundary sections elsewhere. Martin and Macdougall (1991) reported values of 0.707920 in foraminifera from four sedimentary cores in the Atlantic and Pacific oceans. Even higher values of 0.707980 were reported by Hess et al. (1986). The similarity of these values to ours is consistent with the hypothesis that both the Mississippi and New Jersey material is from near or at the K/T boundary.

On the other hand, McArthur et al. (1998) argued that the high values reported by Martin and Macdougall (1991) and Hess et al. (1986) were erroneous due to analytical and diagenetic artifacts, notably recrystallization. McArthur et al. (1998) did not observe an excursion in $^{87}\text{Sr}/^{86}\text{Sr}$ at the K/T boundary in their study of two sections in Denmark and Antarctica. Subsequent studies (MacLeod et al., 2001) have argued for a more modest in-

crease in the ratio of strontium isotopes at the boundary.

Of the samples we analyzed, those from the Owl Creek Formation are more likely to be unaffected by diagenesis because they are very well preserved. In contrast, it is entirely possible that the value of the Parkers Creek material is erroneously high due to diagenetic overprinting, but it is difficult to estimate the extent of this effect. Gallagher (2002) cited secondary mineralization, probably bornite, as the explanation for anomalously high values of $^{87}\text{Sr}/^{86}\text{Sr}$ in the oysters *Pycnodonte dissimularis* from the MFL at the Inversand Pit (Gallagher and Parris, 1996).

Elsewhere in New Jersey, Olsson et al. (2002) reported fluctuations in the ratio of strontium isotopes reaching a maximum of 0.707915 just below the spherule layer in the Bass River borehole. They noted that their values were higher than those reported from France and Tunisia by Vonhof and Smit (1997), and attributed the discrepancy to contamination of the New Jersey samples by clay minerals adhering to the carbonates.

CRETACEOUS/TERTIARY BOUNDARY

The beds comprising the uppermost New Egypt/Tinton Formation and basal part of the Hornerstown Formation in New Jersey have long been regarded as spanning the Cretaceous/Tertiary boundary (Fox and Olsson, 1955; Minard et al., 1969; Owens and Sohl, 1969; Gaffney, 1975; Gallagher et al., 1986; Gallagher, 1995). However, the exact position of the boundary has been disputed. In addition, the formational contact represents an unconformity and it is difficult to assess the length of the time gap, or more properly, the thickness of the chronostratigraphic interval, missing from the section.

Koch and Olsson (1977) investigated the formational contact using dinoflagellates. They reported the *Deflandrea cretacea* [= *Manumiella? cretacea*] Subzone in the upper part of the New Egypt Formation and in the Main Fossiliferous Layer (MFL) at the base of the Hornerstown Formation in the Crosswicks Creek Drainage as well as at the Inversand Pit. According to them, this dinoflagellate subzone corresponds to the foraminiferal *Abathomphalus mayaroensis* Zone,

indicating the upper Maastrichtian. They, therefore, concluded that the formational contact is approximately the same age in both areas and does not mark a major diachronous surface with progressively more erosion to the southwest, as previously proposed by Minard et al. (1969) and Owens and Sohl (1969).

Based on the presence of *Deflandrea cretacea* in the MFL, Koch and Olsson (1977: fig. 4) assigned the basal beds of the Hornerstown Formation to the upper Maastrichtian and placed the Cretaceous/Tertiary boundary at the top of the MFL. Gaffney (1975) and Gallagher (1992) followed this interpretation and drew the K/T boundary in the Inversand Pit at the top of the MFL. However, it is possible that the specimens of *D. cretacea* recorded by Koch and Olsson (1977) were reworked from underlying sediments. Furthermore, Koch and Olsson (1977) did not define what they meant by the MFL and did not specify the position of their sample within this interval. The definition of the MFL varies among authors. For example, our definition of the MFL with respect to the formational contact differs from that of Gallagher (2002). If Koch and Olsson defined the MFL the same way that Gallagher did, and sampled from the bottom of the MFL, their sample would have come from the upper part of the New Egypt Formation, according to our usage (see below).

In a recent paper on the K/T boundary at the Inversand Pit, Gallagher (2002: 295) referred to the presence of late Maastrichtian dinoflagellates in the uppermost part of the New Egypt Formation and basal part of the Hornerstown Formation. He argued that "at most any erosional interval was probably confined to the very latest Maastrichtian and the PO-P α zone of the earliest Paleocene . . . [implying that] the missing interval . . . is at least 100 k.y., the length of the absent earliest Paleocene planktonic foraminiferal zones . . ."

The formational contact at Parkers Creek spans the Cretaceous/Tertiary boundary. The dinoflagellates at the top of the New Egypt Formation indicate the uppermost Maastrichtian (upper part of calcareous nannofossil Subzone CC26b). The concentration of fossils (the MFL) at the base of the Horner-

stown Formation includes reworked material from the New Egypt Formation, implying that part of the Cretaceous section must have been eroded away. However, the reworked ammonites and dinoflagellates are the same species as those present in the underlying New Egypt Formation, so that the missing interval does not exceed an ammonite or dinoflagellate zone.

The nonreworked dinoflagellates in the basal beds of the Hornerstown Formation indicate the lowermost Danian. As previously noted, the lowest occurrences of these dinoflagellates on the Gulf and Atlantic Coastal Plains are in foraminiferal Zones PO-P α . In addition, the upper boundary of the Navesink Sequence in New Jersey is between foraminiferal zones Pla and Plc (Olsson et al., 2002). This boundary is not exposed at Parkers Creek but is present in the Crosswicks Creek Drainage where it occurs approximately 1.5–2 m above the base of the Hornerstown Formation. Therefore, the base of the Hornerstown Formation in the Crosswicks Creek Drainage and, by implication, at Parkers Creek, is probably in Zones PO-P α .

The section at Parkers Creek is, nevertheless, demonstrably incomplete. Neither an enriched layer of iridium (≥ 0.1 ppb) nor a bed of spherules is present (although a dinocyst with pockmarked damage occurs 5–10 cm below the formational contact). Thus, the actual moment marking the K/T boundary is not preserved in the sediments at Parkers Creek. The amount of time missing is difficult to estimate but is probably less than 100 k.y. equal to part of the late Maastrichtian and early Danian, according to the time scale of Berggren et al. (1995).

In contrast, Olsson et al. (1997) described a complete K/T boundary section at Bass River, Burlington County. Using foraminifera, nannofossils, and dinoflagellates, they established that the New Egypt Formation is uppermost Maastrichtian, corresponding to the *Abathomphalus mayaroensis* foraminiferal Zone, and that the Hornerstown Formation is basal Danian, corresponding to planktonic foraminiferal zones PO and P α . There is a 6-cm-thick layer of spherules capping the New Egypt Formation with an iridium anomaly (2.4 ppb) immediately below it.

MAIN FOSSILIFEROUS LAYER

The Main Fossiliferous Layer (MFL) in the basal Hornerstown Formation occurs all along strike from Monmouth to Salem counties, New Jersey, and lies above various lithologies (Minard et al., 1969). It is not present downdip at the Bass River borehole (Olsson et al., 2002). The MFL is roughly similar at all localities but the details appear to vary depending on the site. We refer to several localities where the MFL has been described, but our interpretations principally bear on the Parkers Creek site.

The MFL has been reported in the Crosswicks Creek Drainage, central Monmouth County. Gallagher (1993: 142) described the fossil accumulation as consisting of “a lower thoroughly bioturbated zone . . . topped by a zone with abundant vertebrate remains. This vertebrate fauna is correlative to the vertebrate assemblages found in the basal Hornerstown all along strike. Generally the vertebrates lay on top of a layer rich with invertebrates dominated by *Cucullaea vulgaris*, *Turritella mortoni*, and the oyster *Pycnodonte dissimularis*.”

Our observations of the MFL at Crosswicks Creek are similar to those of Gallagher (1993) and are more fully described in Landman et al. (in prep. b). The MFL consists of a layer of *Cucullaea vulgaris*, not in life position, as well as gastropods, baculites, and vertebrates. All of the molluscs are preserved as internal molds with New Egypt Formation lithology. The MFL lies immediately above a heavily bioturbated, purplish weathering section of the New Egypt Formation, which is 10–25 cm thick, containing scattered internal molds and poorly preserved specimens of *Pycnodonte dissimularis* with original shell material. We recovered *Discoscaphites iris*, *Eubaculites carinatus*, and *E. latecarinatus* from approximately 1–1.3 m below the formational contact.

The most thoroughly studied exposure of the MFL is at the Inversand Pit, Gloucester County. Gallagher (1993: 143) described the MFL at this site as a heavily bioturbated, complex shell bed approximately 30 cm thick. He noted that the base of the MFL is characterized by a layer of *Pycnodonte dissimularis* approximately 10 cm above the for-

mational contact. The specimens are poorly preserved with original shell material and form a densely packed pavement consisting mostly of jumbled up, single valves. According to Gallagher (1993), the top of the MFL is marked by a concentrated layer of molluscan and vertebrate fossils approximately 20 cm above the *P. dissimularis* accumulation. The molluscs, mostly *Cucullaea vulgaris*, are preserved as internal molds with New Egypt Formation lithology. This layer is a mixture of Cretaceous and Paleocene fossils (Gaffney, 1975; Gallagher, 2002). It contains sharks' teeth and fragments of crocodiles, turtles, and mosasaurs, as well as a bird specimen with a partially articulated wing (Gallagher, 1993: 98). This layer also contains small, rare clasts of light tan clay that are apparently different in lithology from either the New Egypt or Hornerstown Formation. Gallagher (1992) did not report any enrichment of iridium in this layer.

The MFL at Parkers Creek is more straightforward and consists of a concentrated layer of molluscan internal molds at the formational contact (figs. 10, 11). Fossils occur below and above the contact, but mostly at the contact, although even here, they are not extremely abundant. All of the molluscs are internal molds with New Egypt Formation lithology. The contact is heavily burrowed but is sharper than in either the Crosswicks Creek Basin or the Inversand Pit. Purplish patches at and just below the contact represent cross sections of burrows infilled with large glauconite grains. This network of burrows is analogous to a sponge with the holes of the sponge representing the burrows. There is no enriched layer of iridium or spherules.

There are two competing hypotheses to explain the processes involved in the formation of the MFL: condensation with little or no sedimentation on the one hand and reworking on the other. Gallagher and his colleagues have argued strongly in favor of a condensed section, partly as a response to earlier arguments by Minard et al. (1969) claiming a major episode of reworking. Gallagher (1993: 116, fig. 12) pointed out a decrease in stratigraphic thickness toward the southwest indicating a “condensation of the section away from the primary source of ter-

restrial clastic deposition in the northeast, where the Redbank and Tinton were laid down as nearshore deltaic deposits”

Gallagher and Parris (1985: C10) suggested that “there was some protracted period of low sedimentation rate usually associated with glauconitic deposition before and during accumulation of the MFL fossil assemblage. This interval argues against the reworking of fossils from underlying Cretaceous units into the basal Hornerstown, since the MFL fossils are not strictly at the bottom of the formation but are separated from it.” Gallagher (1995: 325, 326) speculated that the MFL accumulated over approximately 250,000 years and called it a “time-averaged taphocoenosis” resulting from the accumulation of “skeletal remains undiluted by rapid large-volume deposition of sediment.” He emphasized that the presence of a partially articulated bird wing strongly argues against reworking and in favor of low sedimentation rates with little or no disturbance of organic remains. In a recent publication, Gallagher (2002: 296) expanded on this theme by suggesting that “One possible way to interpret the basal Hornerstown MFL is a condensed section lag, an accumulation of remanié fossils that represent protracted time averaging over the K/T boundary.”

The alternative hypothesis in support of reworking was originally proposed by Minard et al. (1969). Kennedy and Cobban (1996: 799) invoked this hypothesis to explain the concentration of ammonites in the MFL at the Inversand Pit. They concluded that because all of the ammonites are phosphatic fragments of internal molds and are ostensibly absent in the underlying New Egypt Formation, the fossils were reworked from “an underlying unit, or from some now-eroded unit, or have been concentrated by in-situ winnowing.”

There are several pieces of evidence against the hypothesis of condensation and in favor of reworking.

1. The single most persuasive piece of evidence is that all the internal molds of cephalopods, bivalves, and gastropods in the MFL at the Inversand Pit, the Crosswicks Creek Drainage, and Parkers Creek are composed of New Egypt Formation lithology. At Parkers Creek, late Maastrichtian fossils oc-

cur in the uppermost New Egypt Formation, at the formational contact, and up to 13 cm above it. The material in the MFL exhibits a uniformly robust preservation, presumably representing those fossils that survived reworking. That the New Egypt Formation is the source of these fossils is evident not only in their lithology, but by the fact that the same species occur in the top of the New Egypt Formation below the formational contact.

2. Not all vertebrate fossils in the MFL experienced the same taphonomic history. Gallagher (2002) reported differences in the state of preservation of the vertebrates at the Inversand Pit. For example, mosasaur teeth, which are Cretaceous, show more abrasion, presumably due to more reworking, than Paleocene vertebrates. (See Staron et al. [2001] for a discussion of the use of Rare Earth Element [REE] signatures to sort out the taphonomic history of the vertebrate fossils in the MFL at the Inversand Pit.)

3. Gallagher and Parris (1985) stated that the base of the MFL at the Inversand Pit is 10 cm above the formational contact and presented this piece of evidence as an argument against reworking. However, the formational contact may be higher than Gallagher and Parris (1985) supposed. The poorly preserved specimens of *Pycnodonte dissimilaris* are probably in the New Egypt Formation and the accumulation of molluscan internal molds and vertebrates 20 cm above this layer may mark the formational contact and constitute the MFL. This alternative interpretation is consistent with our observations at Crosswicks Creek and Parkers Creek and paves the way for reworking as an explanation for the MFL.

4. Even if the entire unit at the Inversand Pit is interpreted as the MFL, the different layers imply a sequence of different processes to account for their accumulation, not a single process. For example, the layer of *Pycnodonte dissimilaris* with original shell material may be the result of one kind of taphonomic process whereas the layer of molluscan internal molds approximately 20 cm above it may represent another taphonomic process, such as reworking. It is also important to take into account differences in the mineralogy and microstructure of the var-

ious fossils, producing differences in preservational potential.

5. While the presence of an articulated bird wing in the MFL clearly argues against reworking, it also argues against slow sedimentation. An articulated bird wing could not have survived intact on the sea floor over hundreds of thousands of years in a relatively shallow shelf environment (P.J. Harries, personal commun., 2004). It is more likely to have been buried relatively rapidly subsequent to the reworking of other fossils. This is probably true of most Paleocene vertebrates in the MFL, including crocodiles and turtles.

6. The absence of an enriched layer of iridium at Parkers Creek and Sewell is consistent with the hypothesis of reworking and bioturbation spanning the K/T boundary, which would have destroyed any iridium spike. The data are less consistent with the notion of slow, steady, undisturbed sedimentation through the end of the Cretaceous and into the Paleocene. As pointed out by Claeys et al. (2002), an original layer of iridium can be modified by reworking, bioturbation, diagenesis, chemical diffusion, and sediment dilution.

In summary, the sections at the Inversand Pit, Crosswicks Creek, and Parkers Creek indicate the importance of erosion and winnowing to produce a fossil lag deposit. Paleocene vertebrates may have accumulated during the deposition of the sediments covering reworked fossils. Subsequent to the exhumation of the New Egypt Formation fossils, and simultaneously with and subsequent to the deposition of the Paleocene fossils, the sea floor must have experienced extensive bioturbation, which would have produced additional reworking. Burrows filled with large particles can result from the direct activities of burrowing organisms, which ingest fine sediments and leave a residue of larger particles. Alternatively, relict burrows can be passively infilled with larger grains as well as shells (see Aller and Aller, 1986, for modern examples). The high incidence of burrows at the formational contact may reflect the intensified activity of Paleocene animals burrowing into the relatively carbon-rich New Egypt Formation.

The various exposures of the MFL may

represent different levels of chronostratigraphic completeness due to different rates of sedimentation and reworking at each site. More reworking and removal of sediment may have occurred at the Inversand Pit as indicated by the absence of ammonites from the top of the New Egypt Formation, whereas they are present at the top of the New Egypt Formation at Crosswicks Creek and Parkers Creek. Alternatively, these differences may reflect the general scarcity and localized nature of fossils as well as the original distribution of the organisms themselves (see below).

To fully explain the stratigraphic sections in New Jersey, it is necessary to take into account the events inferred to have occurred at the end of the Cretaceous. The best record of what happened in this region at that time is the Bass River borehole, as documented by Olsson et al. (1997, 2002). This site represented a midshelf environment, approximately 100 m deep. An enriched layer of iridium is preserved below a thin bed of spherules (6 cm thick). The spherule bed is capped with a 10-cm-thick layer of glauconitic silty clay with calcareous clay clasts. The clay clasts contain Maastrichtian foraminifera and calcareous nannofossils and the matrix contains Danian foraminifera and dinoflagellates.

Olsson et al. (2002) reconstructed sea level changes at this site and, by implication, on the entire New Jersey coast, by analyzing the sequence of foraminiferal biofacies in the core. They documented a gradual decline in sea level through the late Maastrichtian with a steeper decline starting approximately 22,000 years before the K/T boundary. They estimated that sea level was approximately 50 m above the present level at the K/T boundary and increased slightly thereafter in the early Danian.

These changes in sea level parallel global changes in temperature. Olsson et al. (2001, 2002) studied the biogeographic distribution of planktonic foraminifera in the late Maastrichtian and analyzed the oxygen isotopic composition of their shells. On the basis of these data, they documented a warming trend starting approximately 500,000 years and ending approximately 22,000 years before the K/T boundary. This warming trend co-

incides with the development of the *P. grallator* and *D. iris* zones (R.K. Olsson, personal commun., 2003).

The Bass River core provides evidence for a bolide impact and subsequent tsunami. Olsson et al. (2002) interpreted the spherule layer as fallout from a ballistic vapor cloud produced by a bolide impact. They interpreted the layer of clay clasts above the spherule layer as the result of a tsunami generated by slope failure on the New Jersey margin, following the bolide impact. Because the lithology of these clasts does not match that of the New Egypt Formation, they argued that the clasts were transported shoreward from a deeper water setting. However, it is unclear why such a tsunami would not have destroyed the underlying, fragile layer of spherules.

Bralower et al. (1998), Norris et al. (2000), and Norris and Firth (2002) have also cited evidence for mixing and disturbance of sediment, associated with slumping and mass wasting along the Atlantic continental shelf, produced by an impact at the K/T boundary. These authors hypothesized a catastrophic failure of the western margin of the North Atlantic due to earthquakes associated with the impact, producing composite mass wasting and gravity flows leading to remobilization of sediments.

Gallagher (2002: 296) reinterpreted the MFL at the Inversand Pit in light of these new data: "The MFL fossil bed is the product of tsunami mixing and erosion, creating the formational contact and producing a lag of Cretaceous fossils, over which the remains of Paleocene survivors accumulated during protracted mortality in the wake of the K/T environmental disturbance." He cited evidence of "clay rip-up clasts, small quartz pebbles, and stacked imbricated clusters of single oyster valves at the base of the MFL . . . indicative of sediment disturbance."

In contrast, there are few indications that definitely link the Parkers Creek site with a bolide impact. The section lacks an enriched layer of iridium and no spherules characteristic of the ejecta layer at Bass River have been recovered at the formational contact or in the basal Hornerstown Formation. The only piece of evidence of a bolide impact is a dinoflagellate with pockmarked damage

consistent with melting. However, this damage could equally have been produced by fungal degradation.

The MFL at Parkers Creek is the result of a complex series of events. Winnowing and reworking probably began at Parkers Creek prior to the end of the Cretaceous, coincident with the relatively steep decline in sea level cited by Olsson et al. (2002). The environment at Parkers Creek was shallower than that at the Bass River borehole, approximately 50 m deep, suggesting that it would have been more affected by a drop in sea level. The catastrophic failure of the Atlantic Coastal margin after impact, as documented by Norris et al. (2000) and Norris and Firth (2002), would have caused further remobilization of sediments and reworking, destroying any spherules that may have originally been laid down from the impact. A gradual rise in sea level in the early Danian coincident with the deposition of the Hornerstown Formation would have further reworked, redistributed, and redeposited Cretaceous fossils, at the same time as Paleocene fossils accumulated, producing a mixed assemblage. In this respect, the MFL is similar to lag deposits characteristic of a "transgressive surface of erosion" in a transgressive systems tract (Becker et al., 1996, 1998; Hwang and Heller, 2002). Subsequent burrowing by Paleocene animals would have caused large scale bioturbation.

In summary, there is no unique evidence at Parkers Creek that links the fossil accumulations at this site to the catastrophic events at the end of the Cretaceous. However, the record of these events at the Bass River borehole clearly argues that they must have played a role in producing the fossil deposits at Parkers Creek. The evidence of these events at Parkers Creek may well have been obliterated by erosion and reworking, perhaps associated with the events themselves and subsequent transgression.

DISCOSCAPHITES IRIS ZONE

The *Discoscaphites iris* Zone in New Jersey is not equally fossiliferous everywhere. The ammonites and associated invertebrate fauna are most abundant in the Manasquan River Drainage, central Monmouth County

(Landman et al., in prep. a). The discoscaphites are larger and more numerous at this site than anywhere else. Ammonites are much less abundant at Parkers Creek, Crosswicks Creek, and the Inversand Pit.

This difference in ammonite abundance may reflect preservational factors, notably degree of reworking, as previously noted. However, it may also reflect the preferred habitat of the living organisms in terms of water depth. If we assume that sea level was 50 m above the present level at the K/T boundary (Olsson et al., 2002), we can calculate the approximate water depth at each site in New Jersey by subtracting out its present elevation, assuming that there has been little tectonic movement in the region since the end of the Cretaceous (Miller et al., 2004) and neglecting such factors as sediment loading and compaction. According to these calculations, the Manasquan River Drainage was 20 m deep, whereas all the other sites were 30–50 m deep. Ammonites and other invertebrates may have preferred a shallow water habitat.

In New Jersey, the *D. iris* Zone occupies the uppermost Maastrichtian and is truncated on top by an unconformity spanning the K/T boundary. Fossils from the *D. iris* Zone are reworked into the overlying Paleocene strata. This same pattern appears on the Gulf Coastal Plain.

Kennedy et al. (2001) described the ammonites in the Brazos River section in Falls County, Texas. These ammonites represent the *D. iris* Zone and consist mostly of *Eubaculites carinatus* and *Discoscaphites sphaeroidalis* Kennedy and Cobban, 2000, which is closely related to *D. iris*. These ammonites range through the upper 11 m of the Corsicana Formation and are preserved with their original aragonitic shell. In contrast, the basal part of the Kincaid Formation yields phosphatic, glauconitic fragments of *Eubaculites* and *Discoscaphites*, which were presumably reworked from the underlying Corsicana Formation. According to Hansen et al. (1987), the formational contact marks the K/T boundary (although see Kennedy et al., 2001, for alternative viewpoints on the position of the boundary).

The *D. iris* Zone is present at the classic locality of the Owl Creek Formation on Owl

Creek, Tippah County, Mississippi (Kennedy and Cobban, 2000). The Owl Creek Formation at this site consists of dark greenish gray, micaceous, calcareous, argillaceous, slightly glauconitic sand and is unconformably overlain by the Paleocene Clayton Formation, the base of which is a hard, fossiliferous, sandy limestone (Sohl, 1960: 39). The base of the Clayton Formation contains reworked fossils of Cretaceous age, including *Discoscaphites*. In Hardeman County, Tennessee, the base of the Clayton Formation consists of approximately 1.5 m of marl containing Paleocene fossils as well as reworked fossils from the Owl Creek Formation (Sohl, 1960: 23).

Stephenson (1955) and Campbell and Lee (2000) described the Owl Creek Formation from Crowley's Ridge in Stoddard and Scott counties, southeastern Missouri. The formation at this site consists of yellowish brown and greenish gray, glauconitic, finely micaceous sand or sandy clay and yields *Sphenodiscus pleurisepta*, *Eubaculites carinatus*, and *Discoscaphites iris*. The formation is unconformably overlain by the Clayton Formation, the base of which consists of pale-green, sandy, very glauconitic clay containing a mixture of Cretaceous and Paleocene fossils.

In the Western Interior, the *D. iris* Zone correlates with the dinosaur-bearing strata of the Lance and Hell Creek formations and their equivalents. The confirmed highest occurrence of *Jeletzkytes nebrascensis*, and hence the top of the *J. nebrascensis* Zone, is in the lowermost part of the Hell Creek Formation, South Dakota (Hartman and Kirkland, 2002; Cochran et al., 2003). All of the ammonites above the basal Hell Creek Formation are fragmentary specimens and lie well below the Cretaceous/Tertiary boundary. Hoganson and Murphy (2002) reported a fragment of *Discoscaphites* cf. *D. conradi* or *Jeletzkytes* cf. *J. nebrascensis* from the Breien Member of the Hell Creek Formation in south-central North Dakota, the top of which is 46–61 m below the Hell Creek/Fort Union formational contact. Hartman and Kirkland (2002: 292) reported a fragment of *Hoploscaphites*? from the Fort Rice unit in the middle of the Hell Creek Formation above the Breien Member, and speculated

that this specimen was probably the youngest ammonite in the Western Interior. Jeletzky and Clemens (1965) reported a fragment of the early whorls of a scaphite from the Lance Formation approximately 330 m above the top of the Fox Hills Formation in eastern Wyoming. These occurrences of fragmentary scaphites could represent an extension of the *J. nebrascensis* Zone or evidence of a higher, as yet poorly documented zone (Kennedy et al., 1998). However, even these occurrences are probably below the *D. iris* Zone on the Gulf and Atlantic Coastal Plains.

PALEOGEOGRAPHY AT THE K/T BOUNDARY

Knowledge of the paleogeography of North America at the end of the Cretaceous helps in understanding the distribution of ammonite communities at that time as well as informing discussions about the possible consequences of a bolide impact. We reconstruct the paleogeography of the eastern half of North America based on the distribution of the *D. iris* Zone and the location of stratigraphic sections that span the K/T boundary, representing both marine and terrestrial settings (fig. 15, appendix). Some marine sections are stratigraphically complete, with layers of iridium and spherules (e.g., Bass River core, Burlington County, New Jersey; Olsson et al., 1997), indicating that the water was relatively deep or that the site was reflectively far from shore. Most marine sections, however, contain an unconformity at the boundary (e.g., Moscow Landing, Sumter County, Alabama; Habib et al., 1996), but it is generally difficult to assess how much, if any, of the section is missing. Such unconformities, if significant, may indicate that the water was relatively shallow or that the site was relatively close to shore, especially if terrestrial fossils are also present (e.g., Savannah River Site, southwestern South Carolina; Hargrove and Engelhardt, 1997).

The reconstructed paleogeographic map shows the general outline of the eastern half of North America (fig. 15). It is similar to the map prepared by Sohl and Koch (1986, fig. 5.10) for the *Haustator bilira* Assemblage Zone, by Lehman (1987) for the late Maastrichtian, and by Kennedy et al. (1998)

for the *Jeletzkytes nebrascensis* Zone. The shoreline approximately parallels the Fall Line on the Atlantic Coastal Plain and forms a broad embayment on the Gulf Coastal Plain cutting across Mississippi, Tennessee, and Missouri.

The Western Interior Seaway is not shown on the map because of lack of direct evidence. There are no known marine K/T boundary sections in the Western Interior. The site recently described by Terry et al. (2001) in southwestern South Dakota is actually much lower and occurs in the *Hoploscaphites nicolletii* or *Jeletzkytes nebrascensis* Zone (Harries et al., 2002; Palamarczuk et al., 2003). In contrast, Johnson et al. (2002: 504) hypothesized that a marine K/T boundary section may exist in the subsurface in the eastern part of the Williston Basin in central North Dakota.

There is, however, indirect evidence that a portion of the Western Interior Seaway may have persisted until the end of the Cretaceous. The Cantapeta Tongue in the upper one-third of the Hell Creek Formation in south-central North Dakota contains *Ophiomorpha* burrows and sedimentary structures indicative of a marine or brackish water environment (Murphy et al., 2002: 25, 26). Pearson et al. (2002: 164) also reported the presence of sharks and rays tolerant of marine conditions in the top of the Hell Creek Formation up to 3–4.5 m below the K/T boundary in southwestern North Dakota. They also noted the presence of shore birds (*Hesperornithiformes*) up to 10 m below the boundary at these same sites, implying that a marine body of water may have been nearby at the time of deposition. In addition, Wroblewski (2004) described sharks' teeth from the upper Maastrichtian Ferris Formation in southern Wyoming, in association with marine trace fossils and tidally induced sedimentary structures. He reported that the richest assemblage of sharks' teeth was collected 5 m below the K/T boundary in what he interpreted as an interdistributary bay fill as part of a brackish water estuarine system.

SYSTEMATIC PALEONTOLOGY

CONVENTIONS

The ammonites described in this paper are reposited in the Academy of Natural Scienc-

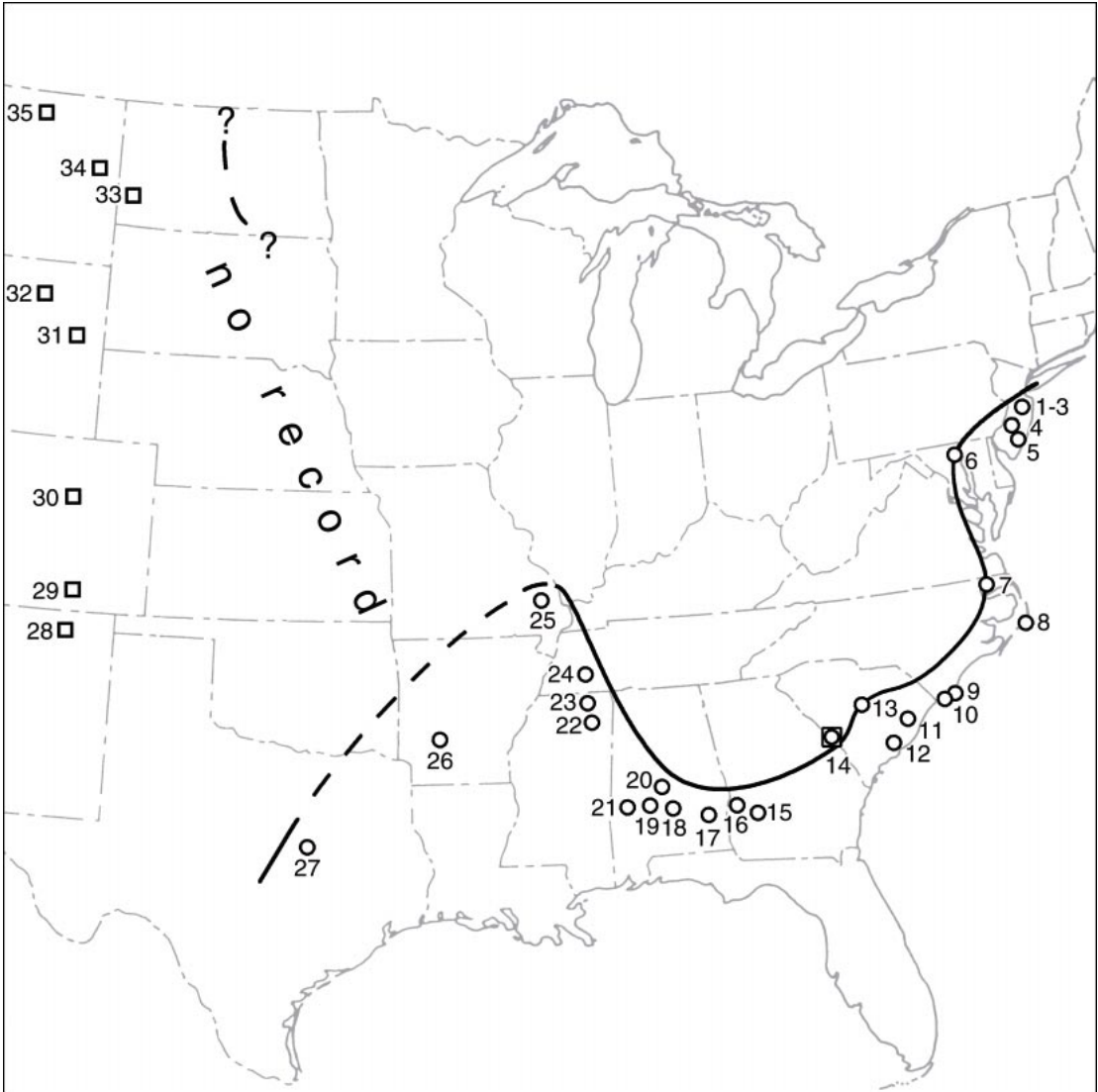


Fig. 15. Paleogeographic map showing the position of the shoreline of the eastern half of North America at the end of the Cretaceous based on stratigraphic sections spanning the K/T boundary. Circles are marine sections; boxes are terrestrial sections; circles within boxes are mixed marine/terrestrial sections. Explanations for 1–27 are in the appendix. 28, 29 = Raton Basin, New Mexico and Colorado (Izett, 1990); 30 = Denver Basin, Colorado (Brown, 1943; Nichols and Fleming, 2002); 31 = Lance Creek area, Wyoming (Bohor et al., 1987); 32 = Powder River Basin, near Sussex, Johnson County, Wyoming (Nichols et al., 1992); 33 = Slope and Bowman Counties, North Dakota (Nichols and Johnson, 2002); 34 = Makoshika State Park, Dawson County, Montana (Lund et al., 2002); 35 = Hell Creek area, Montana (Bohor et al., 1987).

es of Philadelphia (ANSP); the American Museum of Natural History (AMNH); the Monmouth Amateur Paleontologist's Society (MAPS), Long Branch, New Jersey; the University of Iowa (SUI); and the U.S. National

Museum (USNM). Dimensions of the specimens are expressed in millimeters. Measurements of the nautilids, baculites, and scaphites are illustrated in figure 16. Arrows on the photos indicate the base of the body chamber,

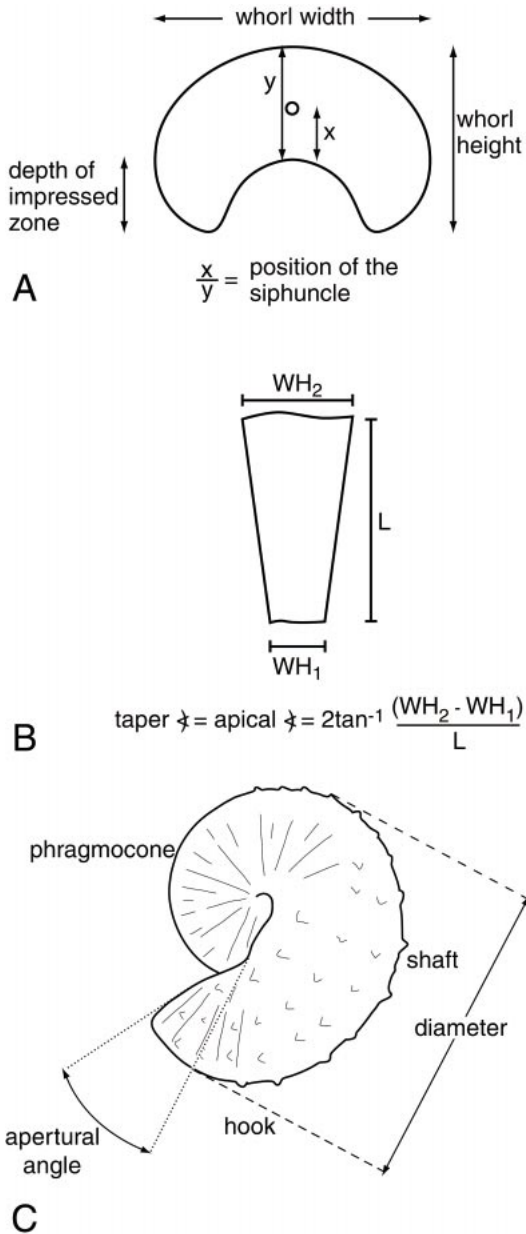


Fig. 16. **A.** Measurements of nautilids. **B.** Definition of taper angle of baculites. **C.** Terminology and measurements of scaphites.

where visible. All specimens were photographed in the conventional manner (with the aperture on top) except for the nautilids, scaphites, and sphenodiscids, which were oriented with the aperture on the bottom, approximating their position in life. Suture ter-

minology is that of Wedekind (1916), as reviewed by Kullmann and Wiedmann (1970). The term "rib index" as applied to baculites is the number of ribs in a distance equal to the whorl height at the midpoint of the interval over which the ribs were counted. The value of the rib index can be an integer or a fraction, although a fractional part of a rib does not make any sense from a practical point of view.

In discoscaphites with multiple rows of tubercles, we report the distance between tubercle rows at midshaft. The distance is also given, if possible, between outer ventrolateral tubercles on either side of the venter. These measurements involve several approximations: (1) the measurements are taken from the tips of the tubercles or, if the tubercles are elongate, from midway on the swellings; (2) the measurements do not take into account the curvature of the flanks (sometimes the tubercles occur on an inflated surface, sometimes on a flat surface); and (3) the measurements are taken to the nearest 0.25 mm.

CLASS CEPHALOPODA CUVIER, 1797

SUBCLASS NAUTILOIDEA AGASSIZ, 1847

ORDER NAUTILIDA AGASSIZ, 1847

SUPERFAMILY NAUTILITACEAE DE
BLAINVILLE, 1825

FAMILY EUTREPHOCERATIDAE MILLER, 1951

Genus *Eutrephoceras* Hyatt, 1894

TYPE SPECIES: *Nautilus Dekayi* Morton, 1834, p. 291, pl. 8, fig. 4, by original designation by Hyatt, 1894, p. 555.

Eutrephoceras dekayi (Morton, 1834)
Figures 17–21

Nautilus Dekayi Morton, 1834: 291, pl. 8, fig. 4.
Nautilus Dekayi Morton. Whitfield, 1892: 243, pl. 37, figs. 1–6; pl. 38, figs. 1–4.

Eutrephoceras Dekayi. Hyatt, 1894: 556, pl. 13, figs. 4–8; pl. 14, fig. 1.

Eutrephoceras dekayi (Morton). Gardner, 1916: 372, pl. 13, fig. 9.

Eutrephoceras dekayi (Morton). Miller and Garner, 1962: 102, figs. 1, 2; pl. 65, figs. 1–6; pl. 66, figs. 1, 2; pl. 67, figs. 1–9 (with complete synonymy).

TYPE: The holotype ANSP 19484 is the

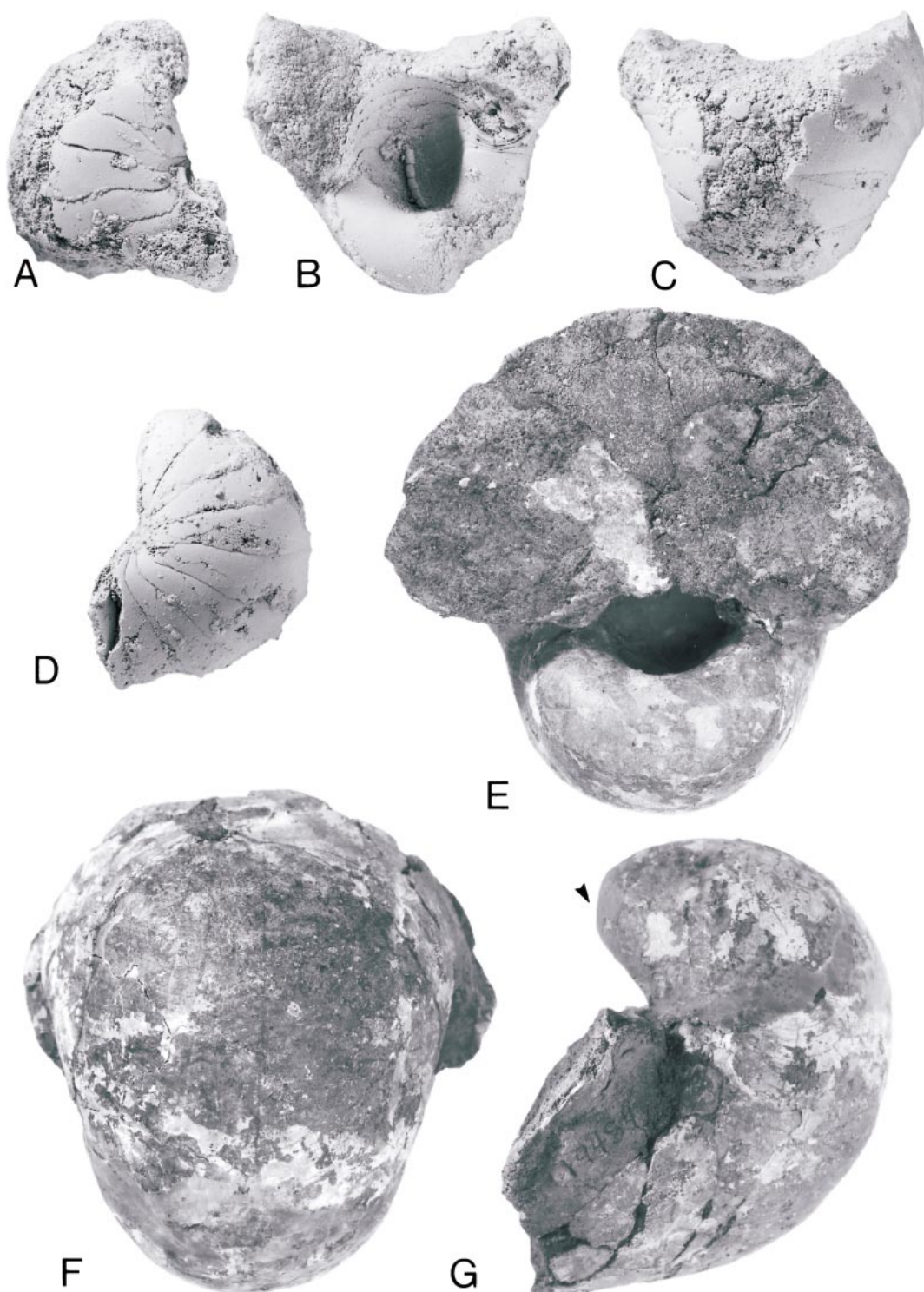


Fig. 17. *Eutrophoceras dekayi* (Morton, 1834). A–D. AMNH 47440, uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County,

original of Morton, 1834, pl. 8, fig. 4, from the “marls of Monmouth and Burlington counties, New Jersey”, by subsequent designation by Whitfield (1892: 213, pl. 37, figs. 2, 3) and illustrated (uncoated) in figure 17E–G. It is labeled as being from Burlington or Monmouth County but Whitfield (1892: 244) identified it as being from Monmouth County. Miller and Garner (1962: fig. 1E) referred to it as being from “the Navesink marl of Monmouth or Burlington County, New Jersey.” It was refigured by Meek (1876: text-fig. 67), Whitfield (1892: pl. 37, figs. 2, 3; pl. 38, fig. 1), Miller (1947: pl. 6, figs. 4, 5), and Miller and Garner (1962: pl. 65, figs. 5, 6). It is a large fragment, one-half whorl long, of a body chamber 80.8 mm in diameter. The apertural margin is slightly flared, suggesting it is an adult. It is gray in color with some preserved shell. On the basis of its preservation, it probably does not come from the Merchantville, Marshalltown, or Tinton formations, nor from the basal Navesink Formation at Atlantic Highlands, nor from the MFL at the base of the Hornerstown Formation. It is probably derived from the upper part of the Navesink Formation in Monmouth County.

MATERIAL: Twenty-eight specimens: MAPS A2012h1 and A2012h2 from AMNH loc. 3346 from the top of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation at Parkers Creek, near Eatontown, Monmouth County, New Jersey; MAPS A2012h3–6 and AMNH 47124–27, 47440–43, and 47463–75 from the top of the New Egypt Formation and the base of the Hornerstown Formation at AMNH loc. 3345 at Parkers Creek, near Eatontown, Monmouth County, New Jersey; and MAPS A2012f7 from the Tinton Formation at Tinton Falls, Monmouth County, New Jersey.

DESCRIPTION: All of the specimens are internal molds without any trace of original shell. Most of them are phragmocones. The measurements are listed in table 4 and indi-

cate a relatively globose shell with a ratio of whorl width to height of 1.39–1.57. The siphuncle is midwhorl to slightly dorsal of midwhorl. The suture is weakly sinuous with low ventral and lateral lobes (fig. 21).

MAPS A2012h2 is one-half whorl of a large body chamber and the last chamber of the phragmocone (fig. 18D–F). The maximum diameter is 101.1 mm. The whorl section at the base of the body chamber is depressed reniform. The ratio of whorl width to height is 1.50. The impressed zone is 0.42 times the whorl height. The siphuncle is relatively central.

MAPS A2012h6 is one-third whorl of a phragmocone 30.0 mm in length consisting of four chambers (fig. 18A–C). The whorl section at the adoral end is depressed reniform with maximum width at one-quarter whorl height. The ratio of whorl width to height is 1.41. The umbilical wall is slightly convex and the umbilical shoulder is fairly abruptly rounded. The flanks and venter are well rounded. The sutures are evenly spaced at distances of approximately 10 mm on the midventer. There are loose fragments of the siphuncle showing the swollen portions between septa and the constricted areas at septal necks.

MAPS A2012h4 is a small, subglobular phragmocone 32.6 mm in diameter (fig. 19H–K). There are 16 chambers. The three most adoral chambers are missing parts of their flanks. The whorl section at the third to last suture is depressed reniform with maximum width at one-third whorl height. The outer flanks and venter are well rounded. The ratio of whorl width to height is 1.46. The umbilicus is tiny, 1.7 mm in diameter. The ratio of umbilical to shell diameter at the third to last suture is 0.06. The sutures are spaced at equal angular increments and are slightly sinuous with weak lateral lobes (fig. 21A). The distance between sutures on the midventer increases gradually from 3.5 mm on the adapical end to 8 mm on the adoral end of the specimen.

←

New Jersey. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–G**. ANSP 19484, holotype, “marls of Monmouth and Burlington counties, New Jersey” (Morton, 1834). **E**, Apertural; **F**, ventral; **G**, left lateral. All figures are $\times 1$.

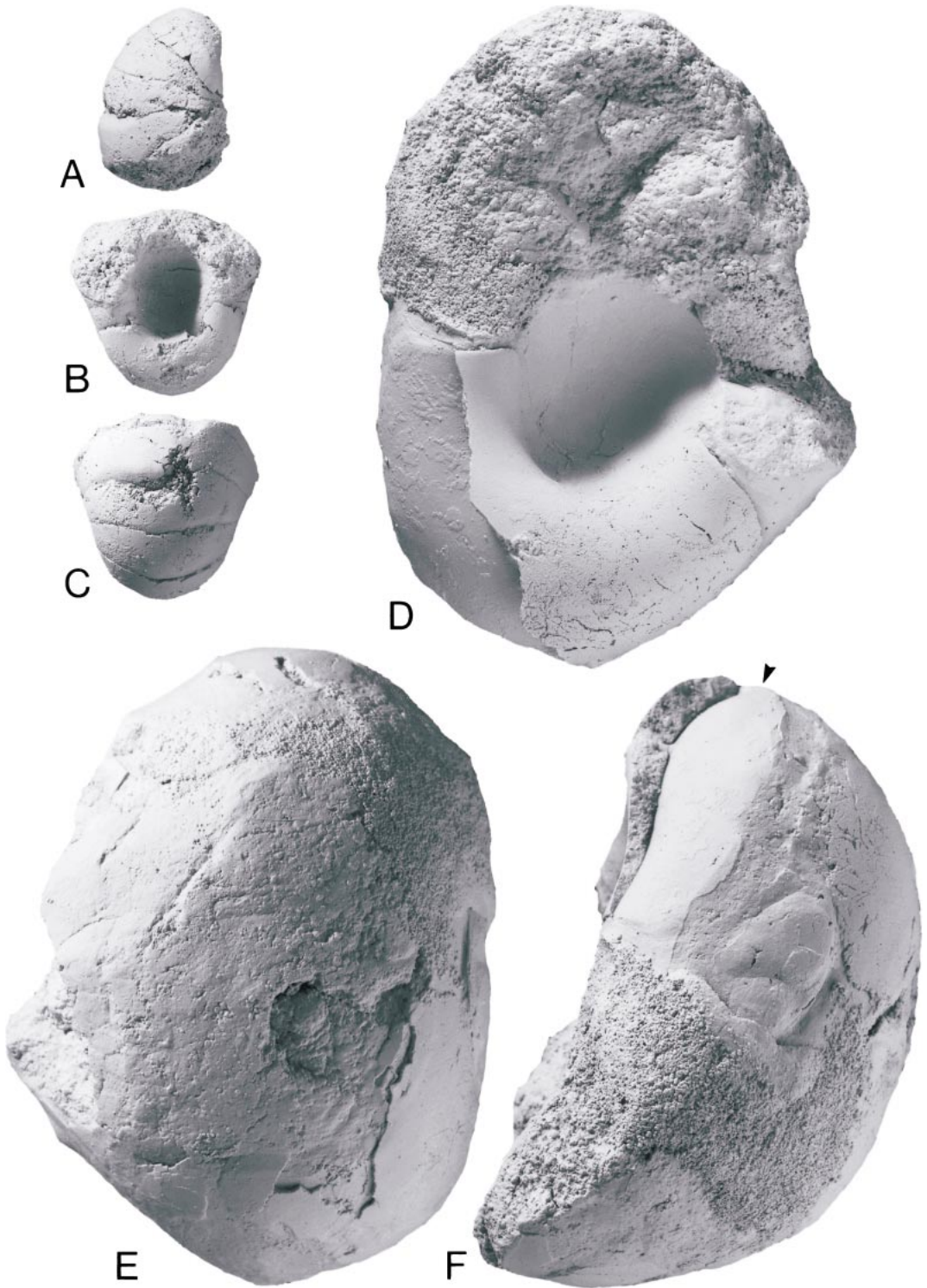


Fig. 18. *Eutrephoceras dekayi* (Morton, 1834). A–C. MAPS A2012h6, uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County,

MAPS A2012h3 is one-third whorl of a phragmocone 58.2 mm in length (fig. 20E–H). There are eight chambers but the specimen is worn away at the adoral and adapical ends. The whorl section is depressed reniform. The ratio of whorl width to height in the middle of the specimen at the third to last suture (where most of the specimen is still intact) is 1.48. The suture shows weak lateral lobes.

AMNH 47442 is one-half whorl of a phragmocone 53.6 mm in diameter (fig. 20A–D). It consists of 11 chambers plus a small part of another chamber. The whorl section at the adapical end of the specimen is depressed reniform with maximum width at one-third whorl height. The ratio of whorl width to height is 1.50. The siphuncle is slightly dorsal of central. The suture is slightly sinuous.

AMNH 47440 is one-third whorl of a phragmocone 39.0 mm in diameter (fig. 17A–D). It is irregularly broken on the adoral end and consists of parts of nine chambers. Interestingly, five segments of the siphuncle are preserved on the middorsum although this was clearly not their original position in life.

AMNH 47441 is a fragment of the adoral end of a phragmocone and adapical part of the body chamber of a small juvenile 24.3 mm in diameter (fig. 19E–G). It consists of three phragmocone chambers and approximately 0.2 whorls body chamber. The whorl section at the adapical end is depressed reniform but the ratio of whorl width to height cannot be measured because of adhering matrix. The body chamber exhibits the midventral line characteristic of nautilids.

AMNH 47443 is a small phragmocone 20.1 mm in diameter consisting of 13 chambers (fig. 19A–D). The umbilicus is small with a diameter of 0.95 mm at a shell diameter of 17.3 mm (ratio of umbilical diameter to shell diameter = 0.05). The ratio of whorl width to height near the adoral end is 1.39. The sutures are slightly sinuous with

weak ventral and lateral lobes and are spaced at equal angular increments.

MAPS A2012h5 (not illustrated) consists of four septate fragments all belonging to the same individual. The composite diameter is 59.5 mm and represents approximately one-half whorl consisting of seven chambers. The whorl width at the adapical and adoral ends is approximately 37.3 and 59.8 mm, respectively, implying an increase in whorl width of 1.6 times.

AMNH 47475 (not illustrated) is one-half whorl of a phragmocone 28.3 mm in length. It consists of two pieces representing a total of six chambers. The suture is slightly sinuous with weak lateral and ventral lobes. The venter bears a distinct midline. The siphuncle is dorsal of center on the fifth to last septum.

MAPS A2012f7 from the Tinton Formation is a globular specimen 84.6 mm in diameter (fig. 19L–N). The last one-half whorl is body chamber. The interior of the phragmocone is filled with fecal pellets. The surface of the phragmocone shows longitudinal ornamentation. The body chamber exhibits a flattened venter.

DISCUSSION: Whitfield (1892) figured five specimens from New Jersey in addition to the type: (1) a small phragmocone from Marlboro, New Jersey (pl. 37, fig. 1), reillustrated by Weller (1907, pl. 100, figs. 2, 3), undoubtedly from the Navesink Formation near Big Brook; (2) a large nearly complete specimen from “Hillsboro, New Jersey” (pl. 37, figs. 5, 6), reinterpreted by Miller and Garner (1962: 110) as probably from “Hillsdale, Monmouth County, where the Red Bank formation occurs”, but whose locality is still unknown; (3) another large specimen from an unidentified locality (pl. 37, fig. 4), then in the collections of the Academy of Natural Sciences of Philadelphia, but now apparently lost; (4) approximately one-half whorl of a phragmocone from Marlboro, New Jersey (pl. 38, fig. 2), reillustrated by Weller (1907: pl. 100, fig. 4), and undoubtedly from the Navesink Formation near Big

←

New Jersey. **A**, Right lateral; **B**, apertural; **C**, ventral. **D–F**. MAPS A2012h2, top of the New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, AMNH loc. 3346, northwest of Eatontown, Monmouth County, New Jersey. **D**, Apertural; **E**, ventral; **F**, left lateral. All figures are $\times 1$.

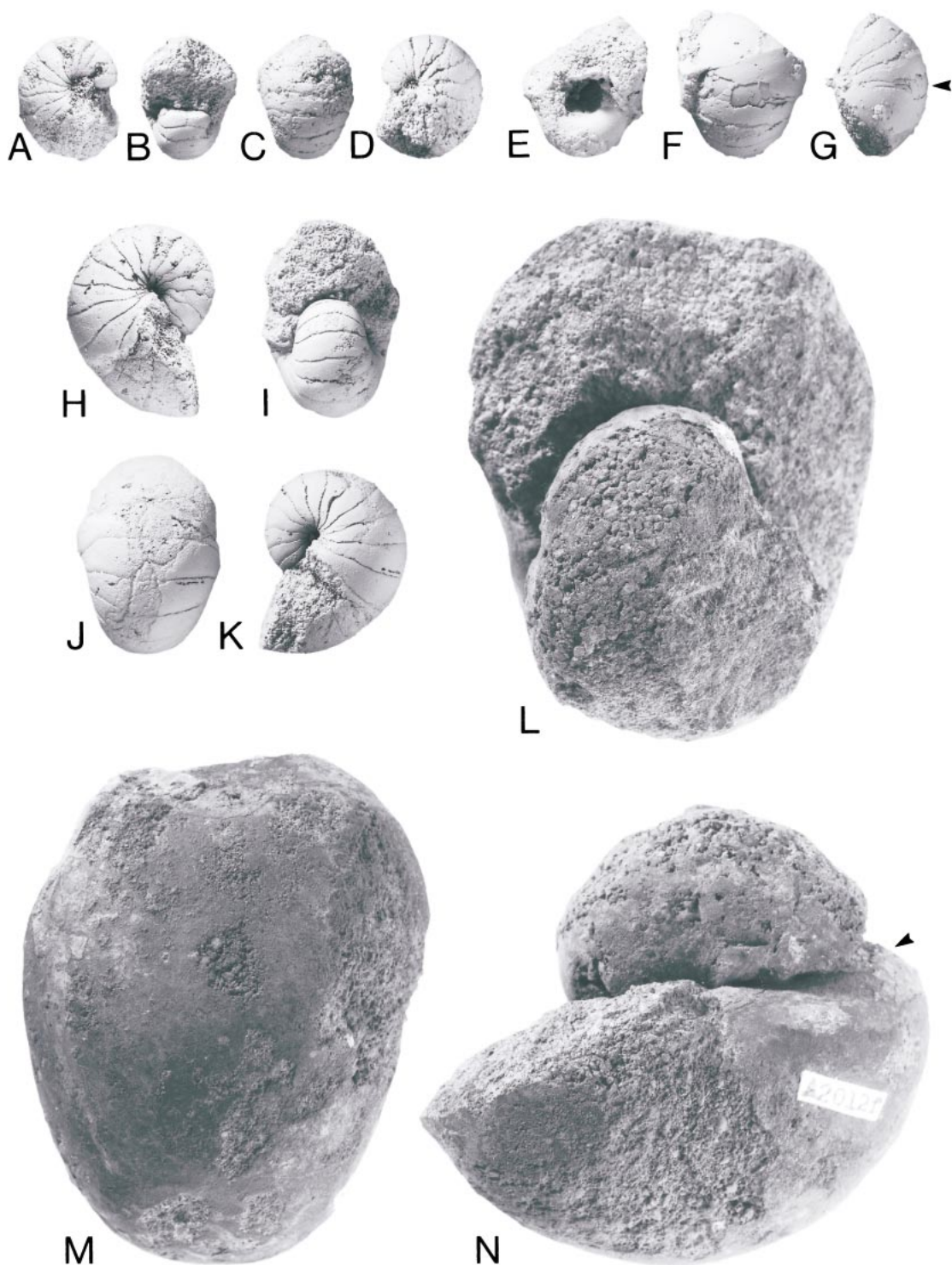


Fig. 19. *Eutrephoceras dekayi* (Morton, 1834). A-K. Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey.

Brook; and (5) a large piece of a phragmocone, approximately one-half whorl, from the "Middle Marls at J. S. Cook's pits, near Tinton, New Jersey" (pl. 38, figs. 3, 4), reillustrated by Weller (1907: pl. 100, fig. 5), who gave the locality as the "Hornerstown marl; Cook's pits near Tinton Falls, New Jersey", and again by Miller (1947: pl. 6, figs. 1–3), who gave the locality as "the Hornerstown marl near Tinton Falls, New Jersey", and probably from the top of the New Egypt Formation or base of the Hornerstown Formation in this area.

Several other specimens of *Eutrephoceras dekayi* have been illustrated from New Jersey. Weller (1907: pl. 100, fig. 1) figured an internal mold of an incomplete specimen of a phragmocone and body chamber from the "Red Bank sand; Shrewsbury River". Miller and Garner (1962: pl. 67, figs. 4, 5) figured a small broken juvenile (SUI 8741) from "the Navesink marl at Glassboro, N.J." and called it *Eutrephoceras dekayi perlatus*. Miller and Garner (1962: pl. 65, figs. 1, 2) also illustrated a larger, broken adult (ANSP 19680) from "Burlington County, N.J.," as the same variety. It appears to be the same specimen figured by Whitfield (1892: pl. 37, fig. 4).

Our specimens, with the exception of MAPS A2012f7, all occur in the upper 2 m of the New Egypt Formation and as reworked material in the basal 6 cm of the Hornerstown Formation. There is little variation in the suture among specimens, which is not unexpected for *Eutrephoceras*. A comparison of the suture of MAPS A2012h4 with another specimen of *E. dekayi* (AMNH 50381) from the basal Navesink Formation at Atlantic Highlands reveals no differences (fig. 21).

On the basis of material from the U.S. Western Interior and Gulf and Atlantic Coastal Plains, Miller and Garner (1962) subdivided *Eutrephoceras dekayi* into three varieties: the nominate variety *E. dekayi dekayi*; *E. dekayi perlatus* after *N[autilus] per-*

latus originally proposed by Morton (1834: 33, pl. 13, fig. 4) for specimens from the Prairie Bluff Chalk of Alabama; and *E. dekayi alcesense* after *Eutrephoceras alcesense* originally proposed by Reeside (1927: 7, pl. 1, figs. 1–3; pl. 2, fig. 1; pl. 3, figs. 1–5; pl. 5, figs. 1, 2) for specimens from the Eagle Sandstone of Montana, Wyoming, Utah, and New Mexico. Miller and Garner (1962) distinguished these varieties on the basis of degree of whorl compression, degree of involution (= depth of impressed zone), and the position of the siphuncle.

We measured the drawings of the whorl sections of the eight specimens figured by Miller and Garner (1962: figs. 1, 2) to obtain a more quantitative understanding of these varieties (table 5). *Eutrephoceras dekayi dekayi* is the most globose of the three varieties with a ratio of whorl width to height of 1.46–1.53. It is moderately involute and the siphuncle is just dorsal of center. The ratio of whorl width to height ranges from 1.18 to 1.26 in *E. dekayi perlatus* but this variety resembles the nominate variety in the other two features. *Eutrephoceras dekayi alcesense* is the most compressed variety with a ratio of whorl width to height of 1.04 to 1.18. It is also the least involute and is characterized by a siphuncle midway between the center and the dorsum.

On the basis of these measurements, the specimens in our study clearly fall in the variety *Eutrephoceras dekayi dekayi*. However, we hesitate to use the varietal names until we perform a more thorough analysis of the variation within a large sample of specimens from a single horizon at one locality. It is possible that the range of variation exhibited by these three varieties is characteristic of a single population. Differences in the degree of whorl compression may reflect sexual dimorphism, as documented in Recent *Nautilus* by Saunders and Spinosa (1978). The position of the siphuncle changes during ontogeny (Stumbur, 1975), and it is important to

←

A–D. AMNH 47443. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. E–G. AMNH 47441. **E**, Apertural; **F**, ventral; **G**, left lateral. H–K. MAPS A2012h4. **H**, Right lateral; **I**, apertural; **J**, ventral; **K**, left lateral. L–N. MAPS A2012f7, Tinton Formation, AMNH loc. 3348, near Tinton Falls, Monmouth County, New Jersey. **L**, Apertural; **M**, ventral; **N**, left lateral. All figures are $\times 1$.

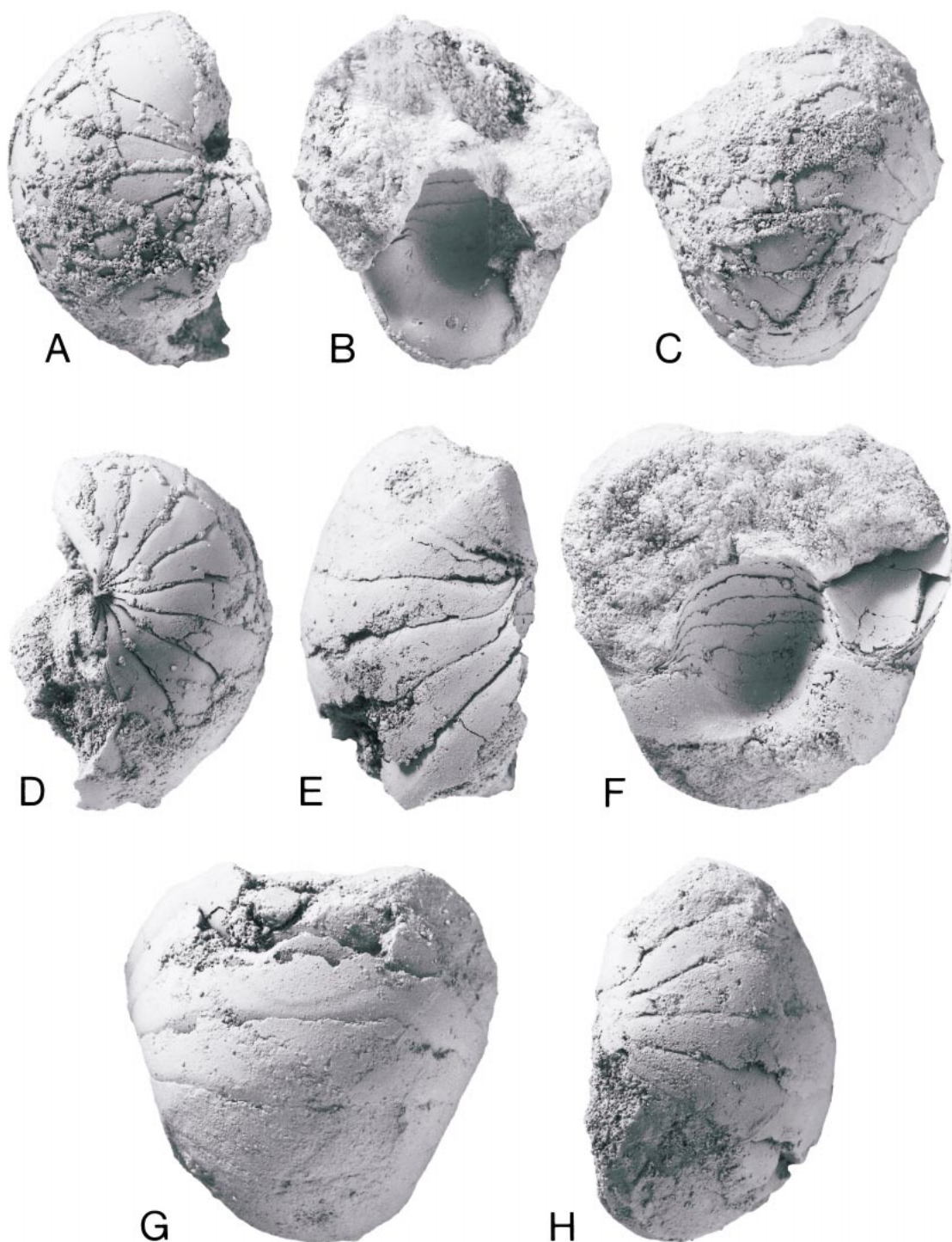


Fig. 20. *Eutrephoceras dekeyi* (Morton, 1834). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–D.** AMNH 47442. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–H.** MAPS A2012h3. **E**, Right lateral; **F**, apertural; **G**, ventral; **H**, left lateral. All figures are $\times 1$.

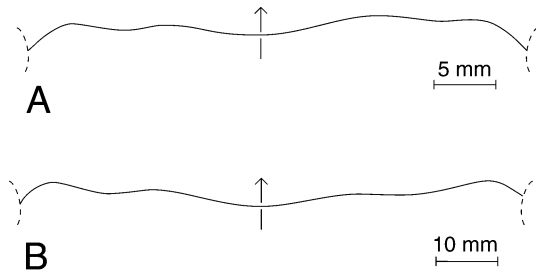


Fig. 21. *Eutrephoceras dekayi* (Morton, 1834). **A.** Suture of MAPS A2012h4 at a diameter of 25.7 mm, AMNH loc. 3345, uppermost New Egypt Formation and basal Hornerstown Formation, northwest of Eatontown, Monmouth County, New Jersey. **B.** Suture of AMNH 50381 at a whorl width of 43.8 mm, basal Navesink Formation, Atlantic Highlands, Monmouth County, New Jersey.

take such information into account in collecting data.

OCCURRENCE: This species occurs in the top 2.0 m of the New Egypt Formation and as reworked material in the basal 6 cm of the Hornerstown Formation, near Eatontown, and in the Tinton Formation, near Tinton Falls, northeastern Monmouth County, New Jersey. It also occurs in the upper part of the Navesink Formation and lower part of the New Egypt Formation in the Crosswicks Creek Drainage, central Monmouth County (Landman et al., in prep. b). It is rare in the Merchantville and Marshalltown formations but relatively common at the base of the Navesink Formation at Atlantic Highlands. Miller and Garner (1962: 109) reported that “In the Cretaceous of New Jersey this species is not abundant, but it occurs in the Navesink marl and the Red Bank sand.” They listed six lo-

calities from the Navesink Formation in Monmouth, Burlington, Camden, and Gloucester counties and one locality from the Red Bank Sand in Monmouth County (as originally reported by Weller, 1907). They speculated that the specimen from the Hornerstown Formation near Tinton Falls, illustrated by Whitfield (1892: pl. 38, figs. 3, 4) and Weller (1907: pl. 100, fig. 5) but unavailable to them for study was a different species. Gallagher (1993: 92) reported that *Eutrephoceras dekayi* is not common in New Jersey but occurs “from the Navesink up into the Hornerstown” and argued that a fragment from the upper part of the Hornerstown Formation at the Inversand Pit probably belongs to this species. Outside of New Jersey, *E. dekayi* is widespread in Campanian to Maastrichtian strata on the Gulf and Atlantic Coastal Plains and in age-equivalent strata in the Western Interior.

TABLE 4
Measurements (mm) of *Eutrephoceras dekayi* (Morton, 1834)^a

	AMNH loc.	D	WW	WH	WW/WH	Depth/WH	Position
MAPS A2012h2	3346	101.1	68.1	45.5	1.50	0.42	0.51
MAPS A2012h3	3345	—	50.4	34.0	1.48	—	—
MAPS A2012h4	3345	32.6	22.0	15.1	1.46	—	—
MAPS A2012h6	3345	—	30.1	21.4	1.41	—	—
MAPS A2012f7	3348	78.8	69.0 ^b	50.5 ^b	1.37 ^b	—	—
AMNH 47442	3345	53.6	28.5	19.0	1.50	—	0.46
AMNH 47443	3345	20.1	15.6	11.2	1.39	—	—
AMNH 47475	3345	—	20.3	12.9	1.57	—	0.37

^aD, maximum diameter (not necessarily where WW and WH were measured); WW, whorl width; WH, whorl height; Depth, depth of impressed zone; Position, relative position of the siphuncle between the dorsum and venter with respect to the dorsum. See figure 16 for an explanation of measurements.

^bEstimate.

TABLE 5
Measurements of *Eutrephoceras dekayi* (Morton, 1834) Described by Miller and Garner (1962: figs. 1, 2)^a

Specimen	Locality	Source	Variety	WW/WH	Depth/WH	Position
SUI 4227	Prairie Bluff Chalk, MS	M&G, 1962, fig. 1C	<i>dekayi</i>	1.46	0.36	0.47
SUI 4230	Pierre Shale, MT	M&G, 1962, fig. 1D	<i>dekayi</i>	1.50	0.37	0.39
ANSP 19484 ^b	Navesink Marl, NJ	M&G, 1962, fig. 1E	<i>dekayi</i>	1.53	0.39	0.42
SUI 4232	Pierre Shale, MT	M&G, 1962, fig. 2A	<i>perlatum</i>	1.18	0.38	0.43
ANSP 19680	Navesink Marl, NJ	M&G, 1962, fig. 2B	<i>perlatum</i>	1.25	0.39	0.46
SUI 4233	Prairie Bluff Chalk, MS	M&G, 1962, fig. 2C	<i>perlatum</i>	1.26	0.38	0.43
SUI 4234	Pierre Shale, MT	M&G, 1962, fig. 1A	<i>alcesense</i>	1.04	0.33	0.22
SUI 8740	Navesink Marl, NJ	M&G, 1962, fig. 1B	<i>alcesense</i>	1.18	0.29	0.18

^aSee table 4 for explanation of abbreviations. Localities are as reported in Miller and Garner (1962). Sources are figures from Miller and Garner (1962).

^bHolotype.

ORDER AMMONOIDEA ZITTEL, 1884

SUBORDER AMMONITINA HYATT, 1889

SUPERFAMILY ACANTHOCERATACEAE DE
GROSSOUVRE, 1894

FAMILY SPHENODISCIDAE HYATT, 1900

Genus *Sphenodiscus* Meek, 1871

TYPE SPECIES: *Ammonites lenticularis*
Owen, 1852: 579 (non Young and Bird,
1828: 269, fig. 5), by original designation, =
Ammonites lobata Tuomey, 1856: 168.

Sphenodiscus pleurisepta (Conrad, 1857)
Figure 22

Ammonites pleurisepta Conrad, 1857: 159, pl. 15,
fig. 1.

Sphenodiscus lenticularis (Owen). Kellum, 1962:
68, pl. 4, figs. 3, 4; pl. 5, fig. 1; pl. 6, figs. 1, 2.

Sphenodiscus pleurisepta (Conrad, 1857). Cobban
and Kennedy, 1995: 12, fig. 8.5 (with full syn-
onymy).

Sphenodiscus pleurisepta (Conrad, 1857). Ken-
nedy et al., 1996: 11, figs. 4A, 5–12.

TYPE: The holotype is USNM 9888, said

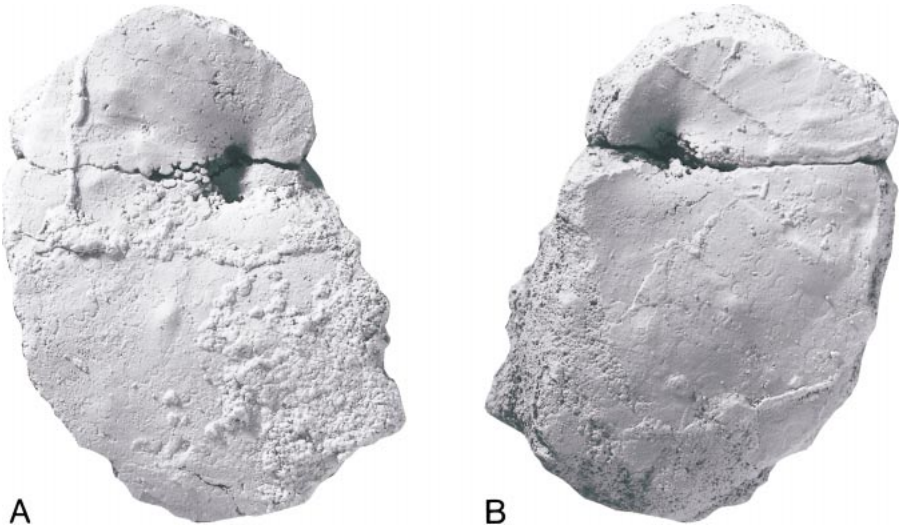


Fig. 22. *Sphenodiscus pleurisepta* (Conrad, 1857). AMNH 47118, uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County. **A**, Right lateral; **B**, left lateral. All figures are $\times 1$.

to be from “Jacun, 3 miles below Laredo”, but probably from the Escondido Formation in the Rio Grande Region, Maverick County, Texas (Stephenson, 1941, 1955).

MATERIAL: AMNH 47118 from the New Egypt/Hornerstown formational contact, AMNH loc. 3345, Parkers Creek, near Eatontown, Monmouth County.

DESCRIPTION: AMNH 47118 is a phragmocone 69.8 mm in diameter with part of the innermost flanks missing and most of the venter worn off (fig. 22). The specimen is involute with a very small umbilicus. The umbilical wall is steep and convex and the umbilical shoulder is sharply rounded on the adapical end of the specimen. The inner flanks are concave and the middle and outer flanks are broadly rounded on the adapical end of the specimen. Rectiradiate, straight, broad ribs are visible on the adapical one-half of the specimen. There is a row of five radially elongated nodes on the midflanks with a distance of approximately 12 mm between the two most adoral nodes. Two nodes are preserved on the outer flanks on the right side.

DISCUSSION: The presence of two rows of nodes on the flanks distinguishes *Sphenodiscus pleurisepta* from the widely occurring *Sphenodiscus lobatus*. Cobban and Kennedy (1995) discussed the synonymy of *S. pleurisepta* and its differences from congeneric species. Because this species has an unusually long range (the entire upper Maastrichtian), it is possible that more than one species is masquerading under this name. It is probably a good idea to closely compare samples of this species from opposite ends of its stratigraphic range.

OCCURRENCE: New Egypt/Hornerstown formational contact, Parkers Creek, near Eatontown, Monmouth County. *Sphenodiscus pleurisepta* has not previously been reported from New Jersey. It also occurs in the Crosswicks Creek Drainage in southwestern Monmouth County (Landman et al., in prep. b). Elsewhere on the Gulf and Atlantic Coastal Plains, this species is known from the Owl Creek Formation in Missouri, Mississippi, and Tennessee (Kennedy and Cobban, 2000), the Prairie Bluff Chalk in Mississippi (Cobban and Kennedy, 1995), the Corsicana Formation in northeast Texas (Kennedy and

Cobban, 1993), and the Severn Formation, Prince Georges and Kent counties, Maryland (Kennedy et al., 1997; Landman et al., 2004). It is known from the Escondido Formation in Trans-Pecos Texas and northern Mexico (Stephenson, 1941, 1955). In the Western Interior, this species occurs in the *Hoploscaphites birkelundae* Zone of the Pierre Shale in Meade and Pennington counties, South Dakota (Kennedy et al., 1996; Larson et al., 1997), the Fox Hills Formation in Niobrara County, Wyoming (Kennedy et al., 1996), and the upper part of the Pierre Shale and Fox Hills Formation in Weld County, Colorado (Kennedy et al., 1996; Landman and Cobban, 2003).

Sphenodiscus lobatus (Tuomey, 1856)

Figures 23–25

Ammonites lenticularis Owen, 1852: 579, pl. 8, fig. 5.

Ammonites lobatus Tuomey, 1856: 168.

Sphenodiscus lobatus (Tuomey, 1856). Cobban and Kennedy, 1995: 12, figs. 6.2, 6.3, 8.4, 8.6–8.11, 12.18, 12.19, 16.16, 16.17 (with full synonymy).

Sphenodiscus lobatus (Tuomey, 1856). Kennedy and Cobban, 1996: 802, fig. 2.4–2.6, 2.13, 2.14, 2.19–2.21.

Sphenodiscus lobatus (Tuomey, 1856). Kennedy et al., 1997: 4, figs. 3–8, 9A–I, 10.

TYPE: The holotype, from Noxubee County, Mississippi, is lost (*vide* Stephenson, 1941: 434).

MATERIAL: There are two specimens: MAPS A2002a8 and A2002a9 from the Tinton Formation, AMNH loc. 3348, 0.2 km north of the intersection of Water Street and Tinton Avenue, Tinton Falls, Monmouth County, New Jersey.

DESCRIPTION: MAPS A2002a9 is one-third whorl of a large phragmocone (not illustrated). The whorl width and height at the adoral end of the specimen are approximately 66.6 mm and 164.0 mm, respectively; the ratio of whorl width to height is 0.41. The flanks are very broadly rounded and converge to an acute venter. Part of the suture on the adapical end of the specimen is illustrated (fig. 25A).

MAPS A2002a8 is a large specimen, 285 mm in diameter, with the adoral end slightly crushed in (figs. 23, 24). Most of the speci-



Fig. 23. *Sphenodiscus lobatus* (Tuomey, 1856). MAPS A2002a8, Tinton Formation, AMNH loc. 3348, Tinton Falls, Monmouth County, New Jersey, left lateral. Note the circular depressions near the base of the body chamber on the adoral end of the specimen. Figure reduced $\times 0.62$.

men is phragmocone with barely less than one-eighth whorl of body chamber attached. However, part of the rest of the body chamber was still present but was not collected in the field because it was too crushed. Three oval to circular depressions appear on the

midflanks of the body chamber on the left side, the largest of which is approximately 16 mm in diameter. The inner flanks are nearly flat and slightly divergent, the midflanks are very broadly rounded and subparallel, and the outer flanks are nearly flat and



Fig. 24. *Sphenodiscus lobatus* (Tuomey, 1856). **A**, **B**. MAPS A2002a8 (same specimen as in fig. 23). **A**, Apertural; **B**, ventral. Figure reduced $\times 0.70$.

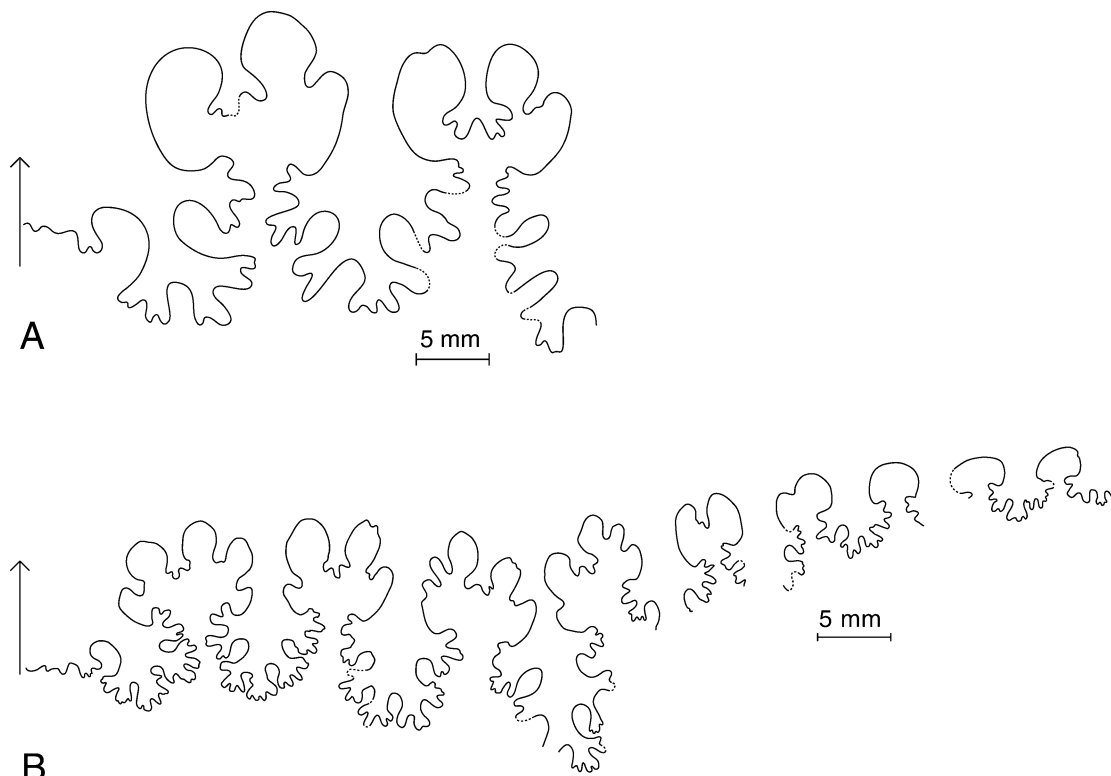


Fig. 25. *Sphenodiscus lobatus* (Tuomey, 1856), Tinton Formation, AMNH loc. 3348, Tinton Falls, Monmouth County, New Jersey. **A.** MAPS 2002a9, suture at the adapical end of the specimen at a whorl height of approximately 139 mm. **B.** MAPS A2002a8, suture at a whorl height of approximately 91 mm.

converge to an acute venter. The whorl width and height near the base of the body chamber are approximately 35.2 mm and 170 mm, respectively, although the whorl width is underestimated due to crushing; the ratio of whorl width to height is 0.21. The flanks are smooth without any nodes. The suture has a very broad and shallow external lobe with a low, little incised median saddle (fig. 25B).

DISCUSSION: These specimens lack the two rows of nodes characteristic of *Sphenodiscus pleurisepta* and are referred to *Sphenodiscus lobatus*. Cobban and Kennedy (1995) fully discussed *S. lobatus* and the differences with congeneric species. The shallow circular depressions and crushed body chamber may indicate predation.

OCCURRENCE: Tinton Formation, near Tinton Falls, northeastern Monmouth County, New Jersey (Weller, 1907; Reeside, 1962;

see also Gallagher, 1993). *Sphenodiscus lobatus* has also been reported in New Jersey from the MFL at the Inversand Marl Pit, Gloucester County (Gallagher, 1993; Kennedy et al., 1995; Kennedy and Cobban, 1996). Elsewhere on the Gulf and Atlantic Coastal Plains, this species is known from the Corsicana Formation in northeast Texas (Kennedy and Cobban, 1993); the upper part of the Ripley Formation in Mississippi; the Prairie Bluff Chalk in Alabama and Mississippi (Cobban and Kennedy, 1995); the Providence Sand in the Chattahoochee River area, Alabama and Georgia; the upper part of the Pee Dee Formation in North Carolina (Landman et al., 2004); and the Severn Formation in Prince Georges County, Maryland (Kennedy et al., 1997). It is known from the Escondido Formation in Trans-Pecos Texas and northern Mexico (Stephenson, 1941, 1955).

In the Western Interior, this species occurs in the *Hoploscaphtes nicolletii* and *Jeletzkytes nebrascensis* Zones of the Fox Hills Formation in north-central South Dakota (Landman and Waage, 1993) and in the *J. nebrascensis* Zone of the Pierre Shale in southeastern South Dakota and northeastern Nebraska (Kennedy et al., 1998).

Sphenodiscus spp.

Figure 26

MATERIAL: There are four specimens that are too fragmentary for specific determination: AMNH 47119, 47122, and 50382 from the New Egypt/Hornerstown formational contact, AMNH loc. 3345, Parkers Creek, near Eatontown, Monmouth County, New Jersey; and AMNH 47170 from the upper part of the New Egypt Formation, approximately 2–2.5 m below the base of the Hornerstown Formation, AMNH loc. 3350, a tributary of Hockhockson Brook, 0.7 km southwest of the intersection of Water Street and Tinton Avenue, Tinton Falls, Monmouth County, New Jersey.

DESCRIPTION: AMNH 47119 (fig. 26) and 47122 (not illustrated) are pieces of phragmocones. Both specimens are badly worn with etched sutures. Neither specimen bears any trace of nodes. AMNH 47119 consists of two fragments with a preserved whorl height of 86 mm. It is broken in half and shows an oxyconic whorl section. Part of the left side is covered with botryoidal swellings, possibly due to a parasitic infestation or more probably a diagenetic phenomenon. AMNH 47122 consists of four pieces, the largest of which has a preserved whorl height of 77 mm.

AMNH 47170 is a fragment of an internal mold of a large body chamber with most of the venter missing (not illustrated); it is 230 mm in maximum length. The whorl section is oxyconic with a sharply rounded venter. The specimen is poorly preserved but exhibits a weak swelling on the outer flanks.

DISCUSSION: These specimens are too fragmentary for specific identification. AMNH 47170 shows a weak swelling on the outer flanks indicating that it may be related to *Sphenodiscus pleurisepta*. The other speci-

mens do not show any evidence of nodes, suggesting kinship with *S. lobatus*.

OCCURRENCE: These specimens occur at the New Egypt/Hornerstown formational contact, AMNH loc. 3345, Parkers Creek, near Eatontown, and 2–2.5 m below the base of the Hornerstown Formation, AMNH loc. 3350, near Tinton Falls, Monmouth County, New Jersey.

SUBORDER ANCYLOCERATINA WIEDMANN, 1966

SUPERFAMILY TURRILITACEAE GILL, 1871

FAMILY BACULITIDAE GILL, 1871

[= EUBACULITINAE BRUNNSCHWEILER, 1966]

Genus *Eubaculites* Spath, 1926

TYPE SPECIES: *Baculites vagina* Forbes var. *ootacodensis* Stoliczka, 1866: 199, pl. 90, figs. 14, ?15, by original designation by Spath, 1926: 80.

Eubaculites carinatus (Morton, 1834)

Figures 27–29, 30A, B, 33U–Y

Baculites carinatus Morton, 1834: 44, pl. 13, fig. 1.

Baculites lyelli d'Orbigny, 1847: pl. 1, figs. 3–7.

Baculites tippaensis Conrad, 1858: 334, pl. 3, fig. 27.

Baculites spillmani Conrad, 1858: 335, pl. 35, fig. 24.

Baculites sheromingensis Crick, 1924: 139, pl. 9, figs. 1–3.

Eubaculites lyelli (d'Orbigny, 1847). Kennedy, 1987: 195, pl. 27, figs. 5–8; pl. 32, figs. 13, 14 (with full synonymy).

Eubaculites carinatus (Morton, 1834). Klinger and Kennedy, 1993: 218, text-figs. 7a–e, 21–30, 31a–g, 32–35, 36e, f, 37, 38, 42a, 52g, h.

Eubaculites carinatus (Morton, 1834). Kennedy and Cobban, 2000: 180, pl. 2, figs. 1–23, 27, 28; text-figs. 3, 4 (with additional synonymy).

Eubaculites carinatus (Morton, 1834). Kennedy et al., 2001: 168, fig. 4a, e.

TYPE: The holotype, by monotypy, is ANSP 72866, the original of Morton, 1834: pl. 13, fig. 1, from the Maastrichtian Prairie Bluff Chalk of Alabama.

MATERIAL: There are 77 specimens, 5 of which are float, from the upper part of the New Egypt Formation and basal part of the Hornerstown Formation, AMNH loc. 3345, Parkers Creek, northeastern Monmouth County, New Jersey, and 1 specimen

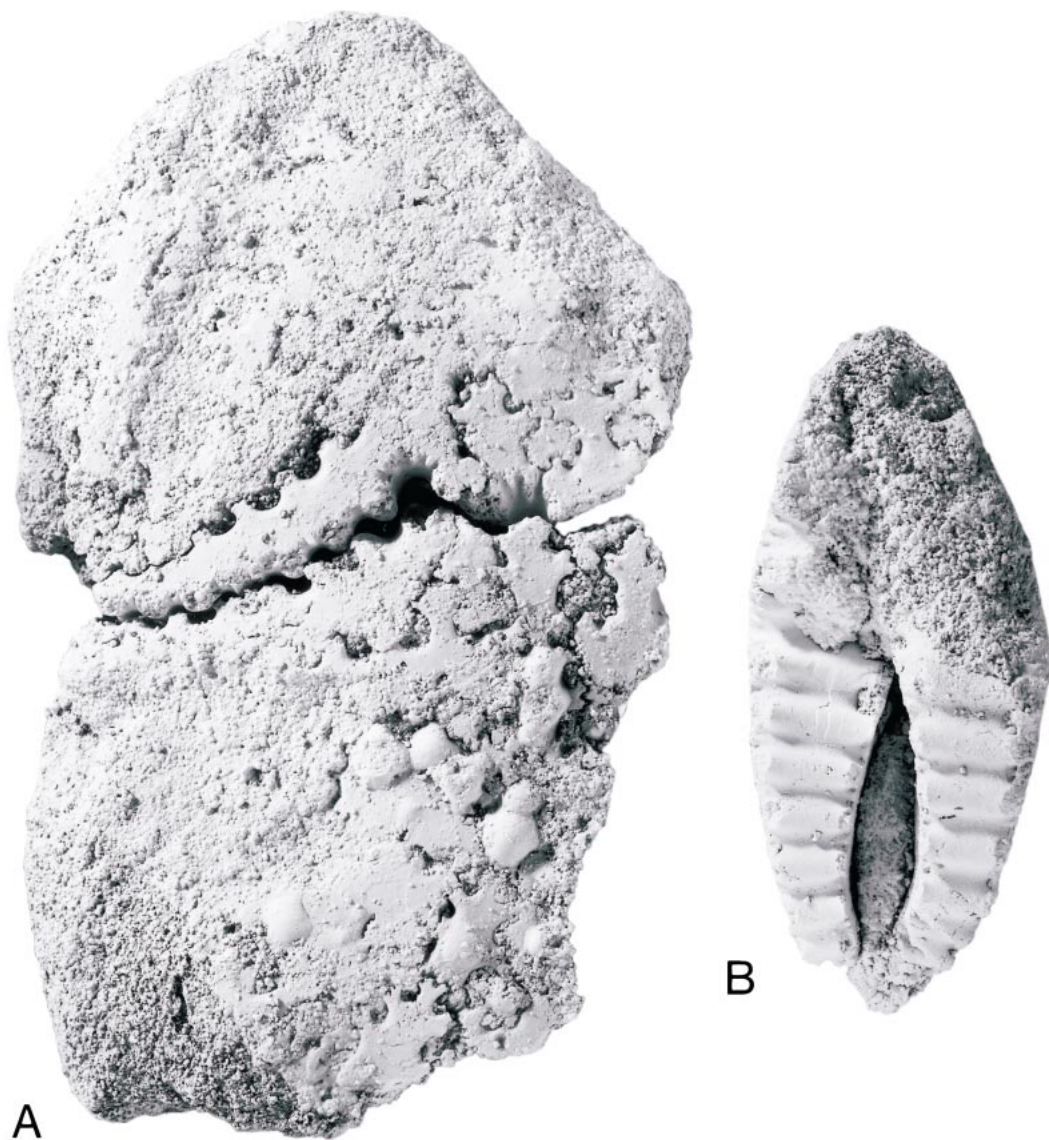


Fig. 26. *Sphenodiscus* sp. AMNH 47119, uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A**, Left lateral of phragmocone fragment; **B**, apertural of part of specimen. All figures are $\times 1$.

(AMNH 47159) from 1.5–2 m below the base of the Hornerstown Formation, AMNH loc. 3346, just upstream from AMNH loc. 3345. All of the specimens are internal molds of fragments less than 75 mm in length. A few specimens retain the original shell material of the septa. There are many more body chamber pieces than phragmocone pieces—there are only four completely septate fragments (5% of the total).

DESCRIPTION: The collection includes both robust and slender forms, presumably macroconchs and microconchs, respectively. These differences are expressed in the angle of taper, although this is also very dependent on ontogenetic stage (table 6). The dorsal one-half of the flanks are covered with broad, asymmetrically crescentic ribs with a rib index of 2–3. The narrow tabulate venter is serrated with a rib index of 6–8. We describe

and illustrate 15 specimens to convey the range of variation of our material.

AMNH 47418 is a piece of body chamber 49.7 mm long with whorl heights of 15.1 and 17.1 mm at the adapical and adoral ends, respectively (fig. 27F–H). The angle of taper is 3.2° . The whorl section at the adoral end is ovoid with maximum width at one-third whorl height both costally and intercostally; the intercostal ratio of whorl width to height is 0.60. The dorsum is very broadly rounded and the dorsolateral shoulder is fairly abruptly rounded. The flanks are broadly rounded and converge to the venter. The narrow, flat venter is bordered by a faint longitudinal groove.

The dorsum shows low, convex folds spaced at distances of approximately 5 mm near the adoral end. There are four large, slightly crescentic nodate swellings on the inner two-thirds of the flanks. The swellings become progressively more widely spaced adorally; the distance between the two most adoral swellings is approximately 14 mm; the rib index is approximately 2. The nodes are strongest just ventral of the dorsolateral margin. The venter is covered by coarse, swollen ribs that show a slight forward projection. They gradually become more widely spaced adorally so that the distance between rib crests at the adoral end of the specimen is approximately 4 mm; the rib index is 6.

AMNH 47506 is a body chamber fragment 56.9 mm long with whorl heights of 11.7 mm and 13.4 mm at the adapical and adoral ends, respectively (fig. 27Q–T). The angle of taper is 3.0° . The ratio of whorl width to height at the adoral end is 0.70. There are low folds on the dorsum. The inner two-thirds of the flanks bear strong crescentic ribs spaced at distances of approximately 10 mm at the adoral end; the rib index is 2.5. The narrow, tabulate venter is ornamented with strong, transverse ribs with a slight adoral projection, producing a serrated appearance; the rib index is 5.

AMNH 47409 is a large fragment of a body chamber 58.2 mm long with whorl heights of 16.7 mm and 19.0 mm at the adapical and adoral ends, respectively (fig. 28H–K). The ratio of whorl width to height at the adoral end is 0.72. The whorl section is ovoid with maximum width at one-third

whorl height. The dorsum is flat and the dorsolateral margin is fairly sharply rounded. The inner flanks are broadly rounded and the outer flanks converge toward the venter. The venter is set off by a weak, longitudinal furrow and the ventrolateral shoulder is fairly abruptly rounded; the venter is narrow and flat.

Weak swellings occur on the dorsal one-half of the flanks with a distance of 13.5 mm between the two most adoral swellings; the rib index is approximately 2.5. The venter is covered with swollen ribs that show a slight forward projection. The ribs are spaced at distances of 4 mm so that the rib index is approximately 6.5.

AMNH 47412 is the adapical part of a body chamber 48.4 mm long (fig. 28L–P). The whorl heights are 14.1 mm and 15.7 mm at the adapical and adoral ends, respectively. The whorl section at the adoral end is pyriform with an intercostal ratio of whorl width to height of 0.73. The angle of taper is 2.2° . The dorsum is nearly flat to very broadly rounded and the dorsolateral margin is fairly abruptly rounded. The flanks are broadly rounded with maximum width at one-third whorl height. The outer flanks converge to the venter. The venter is flat and narrow and is bordered by a ventrolateral furrow producing a keel. The ventrolateral shoulder is abruptly rounded.

There are very faint, convex folds on the dorsum. Broad, crescentic ribs cover the dorsal one-half of the flanks. On the left side, these ribs are of variable strength and spacing with a rib index of 4, whereas on the right side, these ribs are more nodate with a rib index of 2. Ribs slant strongly forward to the ventrolateral margin. The venter is covered with fairly coarse ribs, which show a weak forward projection, producing a serrated appearance; the rib index is 8.

AMNH 47416 is a fragment of a body chamber 45.6 mm long with whorl heights of 13.9 mm and 17.5 mm at the adapical and adoral ends, respectively (fig. 28Q–T). The ratio of whorl width to height at the adoral end is 0.69. Broad, weak crescentic swellings cover the dorsal one-half of the flanks with a rib index of approximately 3. The left side shows a dent near the adapical end, which is probably the result of an injury. The venter

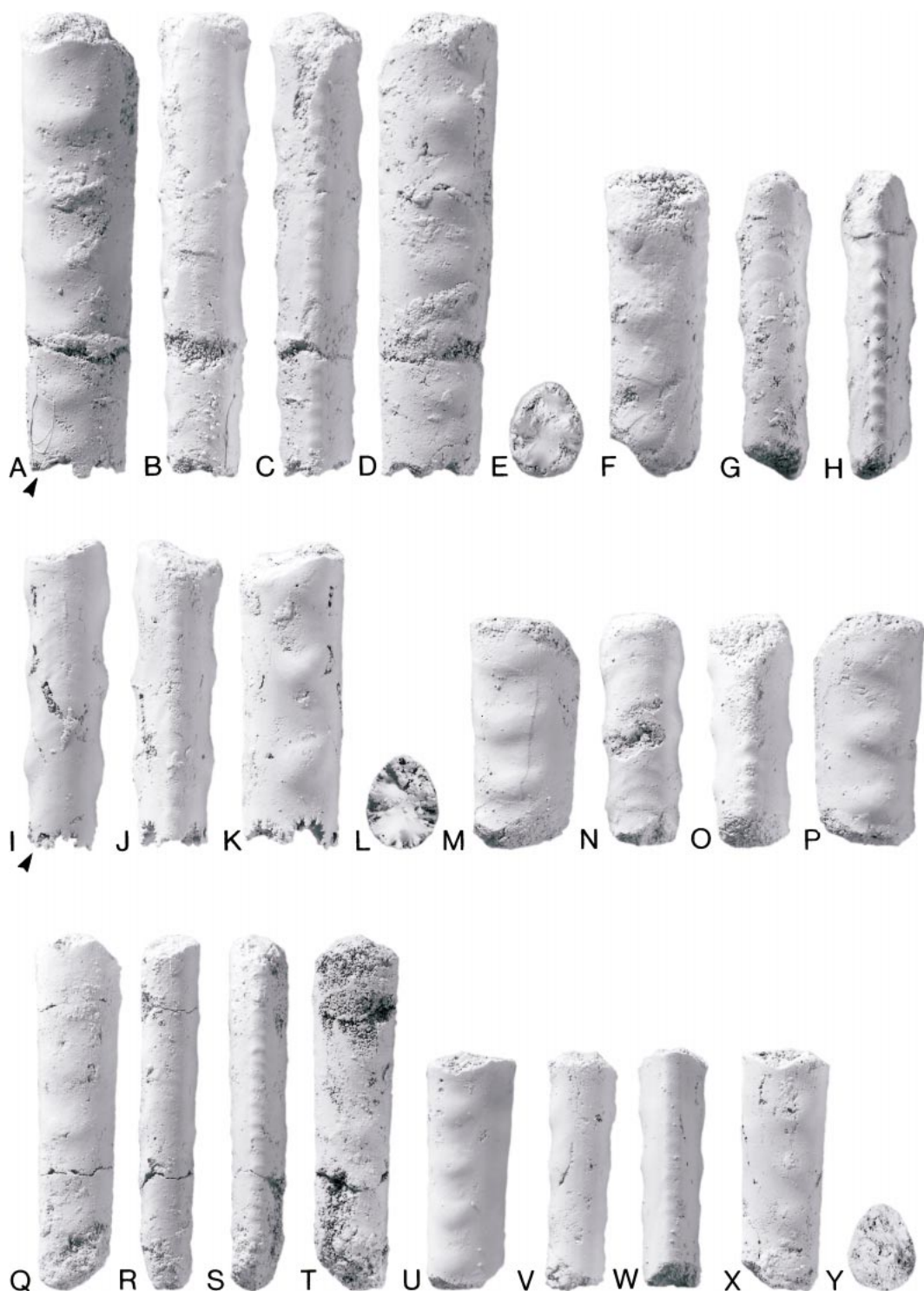


Fig. 27. *Eubaculites carinatus* (Morton, 1834). Uppermost New Egypt Formation and basal Horners-town Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. A–E.

is mostly eroded away but shows three swollen transverse ribs on the adoral end. The ribs are spaced at distances of 2 mm so that the rib index is approximately 10.

MAPS A2058a4 is a strongly ribbed fragment of a body chamber 59.7 mm long with whorl heights of 15.6 mm and 16.4 mm at the adapical and adoral ends, respectively (fig. 29A–E). The intercostal ratio of whorl width to height at the adoral end is 0.70. The angle of taper is 1.2° . There is a shallow, longitudinal groove on either side of a fastigate to tabulate venter. The dorsum is covered with low folds that show a relatively strong adoral projection. There are broad, asymmetrically crescentic ribs on the dorsal one-half of the flanks with a rib index of 3. The venter is notched with swollen ribs showing a slight adoral projection; the rib index is 5.5.

AMNH 47410 is a body chamber fragment with some iridescent shell on the adapical end; the angle of taper is 3.8° (fig. 29F–I). It is 46.5 mm long with whorl heights of 13.4 mm and 15.7 mm at the adapical and adoral ends, respectively. The intercostal ratio of whorl width to height at the adoral end is 0.73. The whorl section is pyriform with a broadly rounded to flat dorsum and fairly sharply rounded dorsolateral margin. The inner flanks are broadly rounded and the outer flanks converge to the venter. The venter is bordered by a faint longitudinal groove. The ventrolateral shoulder is fairly steeply rounded and the venter is narrow and tabulate. Swollen, concave ribs cover the inner one-half of the flanks. The distance between rib crests is approximately 8 mm near the adoral end so that the rib index is approximately 3. Ribs weaken and break down into riblets on the outer one-third of the flanks. They slant strongly forward at an angle of approximately 20° . The ribs strengthen on the venter and

are spaced every 2 mm near the adoral end, so that the rib index is approximately 7.

AMNH 47511 is a coarsely ornamented fragment of the adapical part of a body chamber 38.8 mm long with whorl heights of 12.5 mm and 15.0 mm at the adapical and adoral ends, respectively (fig. 29J–M). The intercostal ratio of whorl width to height at the adoral end is 0.72. The angle of taper is 4.2° . There are low folds on the dorsum. The inner two-thirds of the flanks bear strong, crescentic ribs spaced at distances of approximately 10 mm at the adoral end, so that the rib index is 2.5. The venter is narrow and tabulate and ornamented with strong, transverse ribs that show a slight adoral projection, producing a serrated appearance; the rib index is 5.

AMNH 47415 is a small specimen of a body chamber 35.6 mm long, with relatively coarse ornament (fig. 29N–R). The whorl heights are 12.3 mm and 14.1 mm at the adapical and adoral ends, respectively. The intercostal ratio of whorl width to height at the adoral end is 0.75. The angle of taper is 3.6° . The inner one-half of the flanks are covered with four slightly crescentic nodelike swellings with the interspaces between them as broad as the swellings themselves. The distance between node crests is 9 mm, so that the rib index is approximately 2.5. The ribs slant strongly forward on the outer one-half of the flanks at an angle of approximately 20° . The narrow tabulate venter is covered with swollen, convex ribs spaced at distances of 2.5–3.0 mm, yielding a rib index of 6.

AMNH 47413 is a small piece of the adoral part of a phragmocone and the adapical part of a body chamber of a specimen 35.9 mm long (fig. 29V–X). The whorl heights at the adapical and adoral ends are 9.2 mm and 11.9 mm, respectively. The ratio of whorl width to height at the adoral end is 0.75. The

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MAPS A2058a1. **A**, Right lateral; **B**, dorsal; **C**, ventral; **D**, left lateral; **E**, whorl cross section at adoral end. **F–H**. AMNH 47418. **F**, Right lateral; **G**, dorsal; **H**, ventral. **I–L**. MAPS A2058a2. **I**, Dorsal; **J**, ventral; **K**, left lateral; **L**, whorl cross section at adoral end. **M–P**. AMNH 51064. **M**, Right lateral; **N**, dorsal; **O**, ventral; **P**, left lateral. **Q–T**. AMNH 47506. **Q**, Right lateral; **R**, dorsal; **S**, ventral; **T**, right lateral. **U–Y**. MAPS A2058a3. **U**, Right lateral, **V**, ventral; **W**, dorsal; **X**, left lateral; **Y**, whorl cross section at adoral end. All figures $\times 1$.

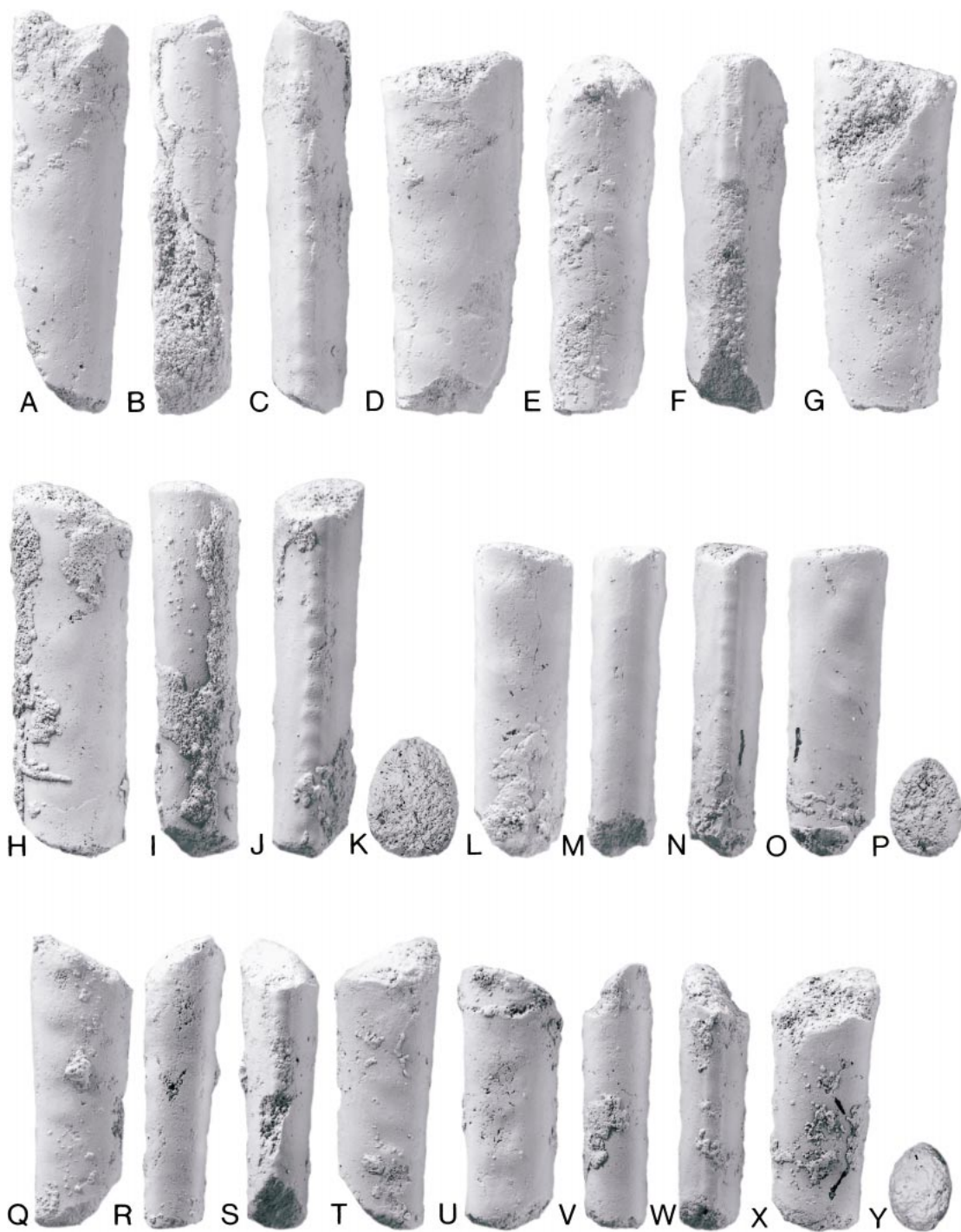


Fig. 28. *Eubaculites carinatus* (Morton, 1834). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–C.** AMNH 47508. **A**, Left lateral; **B**, ventral; **C**, dorsal. **D–G.** AMNH 47272. **D**, Left lateral; **E**, ventral; **F**, dorsal; **G**, right lateral. **H–K.** AMNH 47409. **H**, Right lateral; **I**, ventral; **J**, dorsal; **K**, whorl cross

angle of taper is 5.2° . The inner one-half of the flanks are covered with broad, crescentic ribs with the interspaces between them as broad as the ribs themselves. The distance between rib crests at the adoral end of the specimen is 6 mm; the rib index is approximately 3. The narrow tabulate venter is smooth.

AMNH 47504 is a fragment of a body chamber 35.3 mm long with whorl heights of 9.7 mm and 11.0 mm at the adapical and adoral ends, respectively (fig. 29Y–b). The ratio of whorl width to height at the adoral end is 0.79. The angle of taper is 4.0° . The dorsal one-half of the flanks bear nodelike swellings with a rib index of approximately 2. The ribs weaken and slant strongly forward on the outer one-half of the flanks. They are transverse on the venter, with a rib index of 6.

AMNH 47270 (not illustrated) is a body chamber fragment 55.8 mm long with a whorl height of 22.6 mm at the adoral end. The whorl section is compressed ovoid at the adoral end with a ratio of whorl width to height of 0.75. The dorsum is broad and nearly flat and the dorsolateral shoulder is fairly abruptly rounded. The inner flanks are broadly rounded and nearly parallel and the outer flanks converge toward the venter. The venter is narrow and tabulate and the ventrolateral shoulder is abruptly rounded. There is a shallow longitudinal groove that borders the venter. The dorsum is covered with low, convex folds. The venter is nearly smooth and the dorsal one-half of the flanks bear widely spaced nodelike swellings with a rib index of approximately 2.5.

AMNH 47444 is one of the smallest fragments in our collection, a piece of phragmocone, 13.6 mm in length, with whorl heights of 9.9 mm and 10.6 mm at the adapical and adoral ends, respectively (not illustrated). The ratio of whorl width to height at the adoral end is 0.74. There are two nodelike swellings on the inner flanks with a rib

index of 2. The ribs are very weak on the tabulate venter with a rib index of 4.5 based on a distance of 3 mm between the two most adoral ribs.

MAPS A2058a6 (not illustrated) is a completely septate fragment 63.0 mm long with whorl heights of 16.0 mm and 18.7 mm at the adapical and adoral ends, respectively. The whorl section at the adoral end is compressed ovoid with a ratio of whorl width to height of 0.75. The dorsum is very broadly rounded and the dorsolateral margin is well rounded. The flanks are broadly rounded and converge toward the venter with maximum width at midwhorl height. The venter is bordered by a shallow, longitudinal depression and the ventrolateral shoulder is fairly sharply rounded; the venter is broadly rounded to flat. The inner one-half of the flanks are smooth except for weak, nodelike swellings with a rib index of approximately 2. Broad, transverse ribs cover the venter with a rib index of 7. Parts of the last and next to last suture are illustrated in figure 30B. The sutures are worn but show a bifid L/U, a broad, bifid U, and a narrow I.

AMNH 47159 is a fragment of the adapical end of a body chamber 43.4 mm long with whorl heights of 11.2 mm and 13.4 mm at the adapical and adoral ends, respectively (fig. 33U–Y). The ratio of whorl width to height at the adoral end is 0.74. The venter is narrow and nearly flat and is bordered by a longitudinal furrow. There are weak crescentic swellings on the dorsal one-half of the flanks with a rib index of approximately 3. The venter is ornamented with weak, transverse ribs with a rib index of approximately 8.

DISCUSSION: This species is characterized by a narrow, tabulate venter ornamented with ribs producing a serrated appearance, and broad, asymmetrically crescentic ribs on the dorsal one-half of the flanks. The full range of variation of this species has been recently discussed by Klinger and Kennedy (1993),

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section at adoral end. **L–P.** AMNH 47412. **L**, Right lateral; **M**, ventral; **N**, dorsal; **O**, left lateral; **P**, whorl cross section at adoral end. **Q–T.** AMNH 47416. **Q**, Right lateral; **R**, ventral; **S**, dorsal; **T**, left lateral. **U–Y.** AMNH 47420. **U**, Right lateral; **V**, ventral; **W**, dorsal; **X**, left lateral; **Y**, whorl cross-section at adoral end. All figures $\times 1$.

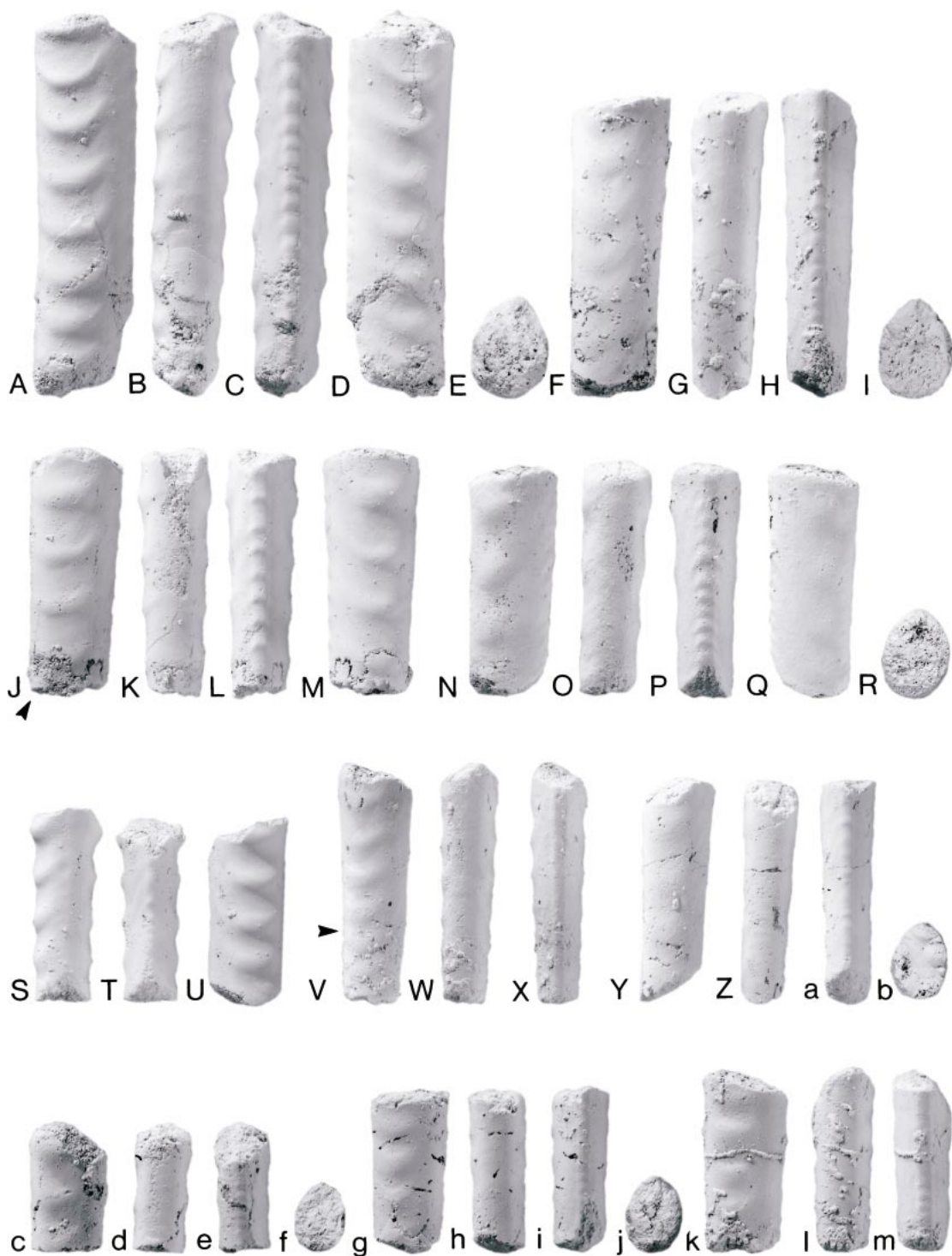


Fig. 29. *Eubaculites carinatus* (Morton, 1834). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. A–E. MAPS A2058a4. A, Right lateral; B, dorsal; C, ventral; D, left lateral; E, whorl cross section at

Cobban and Kennedy (1995), and Kennedy and Cobban (2000).

OCCURRENCE: This species occurs in New Jersey in the upper part of the New Egypt Formation and as reworked material at the base of the Hornerstown Formation, near Eatontown, northeastern Monmouth County; at the top of the New Egypt Formation in the Crosswicks Creek Basin, southwestern Monmouth County (Landman et al., in prep. b); and in the New Egypt Formation at the Inversand Pit, near Sewell, Gloucester County (Kennedy and Cobban, 1996). It also occurs at the top of the Tinton Formation and as reworked material at the base of the Hornerstown Formation near Freehold, central Monmouth County (Landman et al., in prep. a). Kennedy and Cobban (1996: fig. 3.1–3.3, 3.7–3.12) recorded three specimens of this species (USNM 12691a–c), *ex* J.B. Marcou collection, labeled “New Jersey”, which they inferred to be from the base of the Hornerstown Formation. This species is reported elsewhere on the Gulf and Atlantic Coastal Plains from the top of the Corsicana Formation and as reworked material at the base of the Kincaid Formation, Falls County, Texas (Kennedy et al., 2001); the Owl Creek Formation, Mississippi, Missouri, and Tennessee (Kennedy and Cobban, 2000); the Prairie Bluff Chalk, Alabama and Mississippi (Cobban and Kennedy, 1995); and the Severn Formation, Maryland (Kennedy et al., 1997; Landman et al., 2004). It is also reported from southeast France, Austria, the Netherlands, Zululand (South Africa), Mozambique, Madagascar, southern India, Western Australia, Chile, Argentina, and California. It ranges from the upper lower to the upper upper Maastrichtian (Klinger et al., 2001).

Eubaculites latecarinatus (Brunnschweiler, 1966)

Figures 30C, D, 31, 32

Eubaculites otacodensis (Stoliczka). Spath, 1940: 49 (pars), text-fig. 1c.

Giralites latecarinatus Brunnschweiler, 1966: 33, pl. 3, figs. 13, 14; pl. 4, figs. 1–5; text-figs. 17, 18.

Giralites quadrisulcatus Brunnschweiler, 1966: 35, pl. 4, figs. 11–14; text-fig. 20.

Eubaculites ambindensis Collignon, 1971: 18, pl. 646, fig. 2393.

Eubaculites latecarinatus (Brunnschweiler). Klinger, 1976: 91, pl. 40, fig. 1; pl. 41, fig. 3; pl. 42, figs. 2, 6; pl. 43, figs. 3, 4; text-figs. 11d, e.

Eubaculites latecarinatus (Brunnschweiler). Klinger and Kennedy in Klinger et al., 1980: 296, figs. 2a–c, 3a–d, 4a–c, 5b.

Eubaculites latecarinatus (Brunnschweiler, 1966). Henderson et al., 1992: 159, figs. 22L–N, 23N–P.

Eubaculites latecarinatus (Brunnschweiler, 1966). Klinger and Kennedy, 1993: 238, figs. 26A, 39–41, 42B, C, 43–49, 50A, 52A.

Eubaculites latecarinatus (Brunnschweiler, 1966). Kennedy et al., 1997: 20, figs. 15A–D, K, L, 16G, H, 19.

Eubaculites latecarinatus (Brunnschweiler, 1966). Klinger and Kennedy, 2001: 234.

Eubaculites latecarinatus (Brunnschweiler, 1966). Klinger et al., 2001: 287, pl. 10, figs. 4–9; text-fig. 6.

TYPE: The holotype, by original designation, is the original of Brunnschweiler (1966: pl. 4, figs. 2–4) from the Maastrichtian of western Australia.

MATERIAL: There are 94 specimens, 4 of which are float, from the upper part of the New Egypt Formation and basal part of the Hornerstown Formation on Parkers Creek, AMNH loc. 3345, near Eatontown, northeastern Monmouth County, New Jersey. All of the specimens are internal molds of fragments less than 75 mm in length; some of

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adoral end. **F–I.** AMNH 47410. **F**, Right lateral; **G**, dorsal; **H**, ventral; **I**, whorl cross section at adoral end. **J–M.** AMNH 47511. **J**, Right lateral; **K**, dorsal; **L**, ventral; **M**, left lateral. **N–R.** AMNH 47415. **N**, Right lateral; **O**, dorsal; **P**, ventral; **Q**, left lateral; **R**, whorl cross section at adoral end. **S–U.** MAPS A2058a5. **S**, Dorsal; **T**, ventral; **U**, left lateral. **V–X.** AMNH 47413. **V**, Right lateral; **W**, dorsal; **X**, ventral. **Y–Z, a, b.** AMNH 47504. **Y**, Right lateral; **Z**, dorsal; **a**, ventral; **b**, whorl cross section at adoral end. **c–f.** AMNH 47421. **c**, Right lateral; **d**, dorsal; **e**, ventral; **f**, whorl cross section at adoral end. **g–j.** AMNH 47424. **g**, Right lateral; **h**, dorsal; **i**, ventral; **j**, whorl cross section at adoral end. **k–m.** AMNH 47423. **k**, Right lateral; **l**, dorsal; **m**, ventral. All figures are $\times 1$.

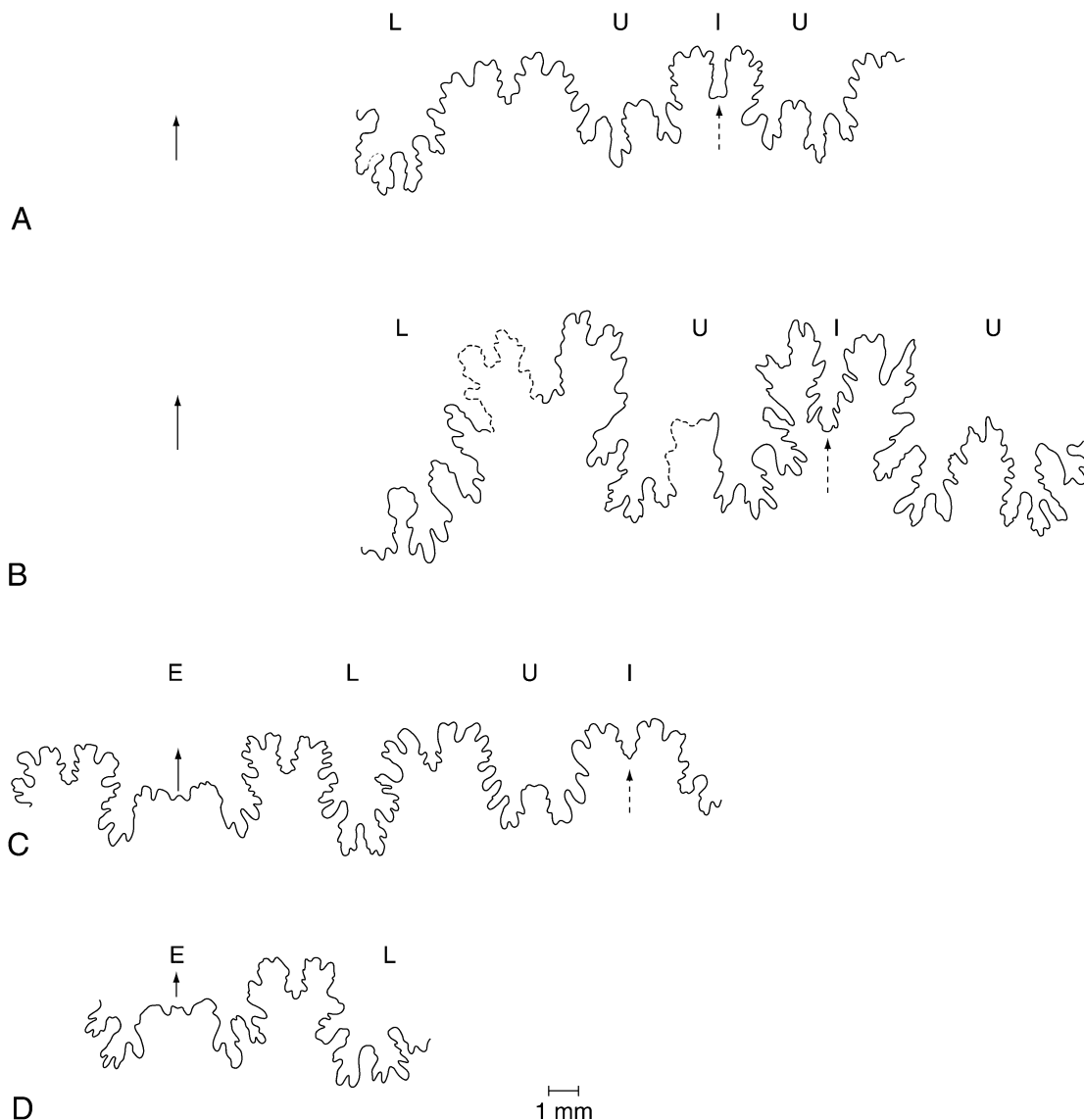


Fig. 30. **A, B.** *Eubaculites carinatus* (Morton, 1834). Uppermost New Egypt Formation and basal Hornerstown Formation, Parkers Creek, northwest of Eatontown, Monmouth County, New Jersey. **A.** AMNH 47253, last suture at a whorl height of approximately 12.9 mm. **B.** MAPS A2058a6, parts of the last and next to last suture at a whorl height of approximately 19.1 mm. **C, D.** *Eubaculites latecarinatus* (Brunnschweiler, 1966), same locality as A, B. **C.** AMNH 47493, last suture and parts of third and fourth to last sutures, at a whorl height of approximately 11.4 mm. **D.** AMNH 47501, at a whorl height of approximately 12.2 mm.

them preserve the original shell material of the septa. Most of the specimens are fragments of body chambers—there are 14 completely septate pieces (15% of the total).

DESCRIPTION: The collection consists of ro-

bust and slender forms that are distinguished, in part, by their angle of taper, although this measurement is very dependent on ontogenetic stage (table 7). These two forms may represent dimorphs, but without better infor-

TABLE 6
Measurements of *Eubaculites carinatus* (Morton, 1834)^a

Specimen	L (mm)	WW/WH	Taper angle (degrees)	Rib index	
				Flanks	Venter
AMNH 47159	43.4	0.74	2.8	3	8
AMNH 47270	55.8	0.75	—	2.5	S
AMNH 47409	58.2	0.72	2.2	2.5	6.5
AMNH 47410	46.5	0.73	3.8	3	7
AMNH 47411	38.8	0.72	4.2	2.5	5
AMNH 47412	48.4	0.73	2.2	2	8
AMNH 47413	35.9	0.75	5.2	3	S
AMNH 47415	35.6	0.75	3.6	2.5	6
AMNH 47416	45.6	0.69	5.8	3	10
AMNH 47418	49.7	0.60	3.2	2	6
AMNH 47421	20.4	0.68	2.6	3	7
AMNH 47444	13.6	0.74	—	2	4.5
AMNH 47448	27.2	0.74	2.2	3	S
AMNH 47504	35.3	0.79	4.0	2	6
AMNH 47506	56.9	0.70	3.0	2.5	5
AMNH 47508	60.2	—	1.4	2	6
AMNH 47509	38.4	0.72	5.2	3.5	8.5
MAPS A2058a6	63.0	0.75	3.2	2	7
MAPS A2058a1	73.1	0.73	2.2	3	7
MAPS A2058a2	33.5	0.79	2.0	2	8.5
MAPS A2058a4	59.7	0.70	1.2	3	5.5
MAPS A2058a3	38.3	0.73	2.8	3	8.5

^aL, maximum length; WW/WH, intercostal ratio of whorl width to height at the adoral end of the specimen; S, smooth. See figure 16 for an explanation of taper angle; if the specimen was partly broken, the length measurement used to calculate the taper angle was less than L.

mation on the ontogenetic stage of the specimens, this conclusion is difficult to prove. We provide descriptions of 15 specimens to cover the range of variation in our collection.

AMNH 47273 is a fragment of the adoral part of a phragmocone and the adapical part of a body chamber of a specimen 56.4 mm long (fig. 31A–E). The whorl heights at the adapical and adoral ends are 15.7 mm and 18.8 mm, respectively. The whorl section at the adoral end is compressed ovoid with a ratio of whorl width to height of 0.66. The angle of taper is 2.8°. The dorsum is covered with weak, broad folds with a strong adoral projection. Ribs are asymmetrically crescentic on the inner one-half of the flanks with a rib index of 7, and slant strongly forward on the outer one-half of the flanks. Ribs are weak and swollen on the venter with a rib index of 6.

AMNH 47414 is a small piece of a body chamber 38.0 mm long with whorl heights

of 15.9 mm and 17.3 mm at the adapical and adoral ends, respectively (fig. 31F–I). The flanks are smooth and the right side is partly covered by a bryozoan colony. The venter is narrow and tabulate without any trace of ribs.

AMNH 47411 is a body chamber fragment 43.4 mm long with whorl heights of 13.4 mm and 15.3 mm at the adapical and adoral ends, respectively (fig. 31J–N). The intercostal whorl section at the adoral end is pyriform with a ratio of whorl width to height of 0.76. The angle of taper is 3.4°. The dorsum is smooth. The inner one-half of the flanks bear crescentic, swollen ribs; the two most adoral ribs on the right side are 6.5 mm apart; the rib index is 4. The ribs slant sharply forward on the outer one-half of the flanks at an angle of approximately 20°. The ribs are faint on the narrow, tabulate venter, with an index of 7.

AMNH 47417 is a fragment of a body chamber 45.7 mm long with whorl heights of 13.7 mm and 14.8 mm at the adapical and

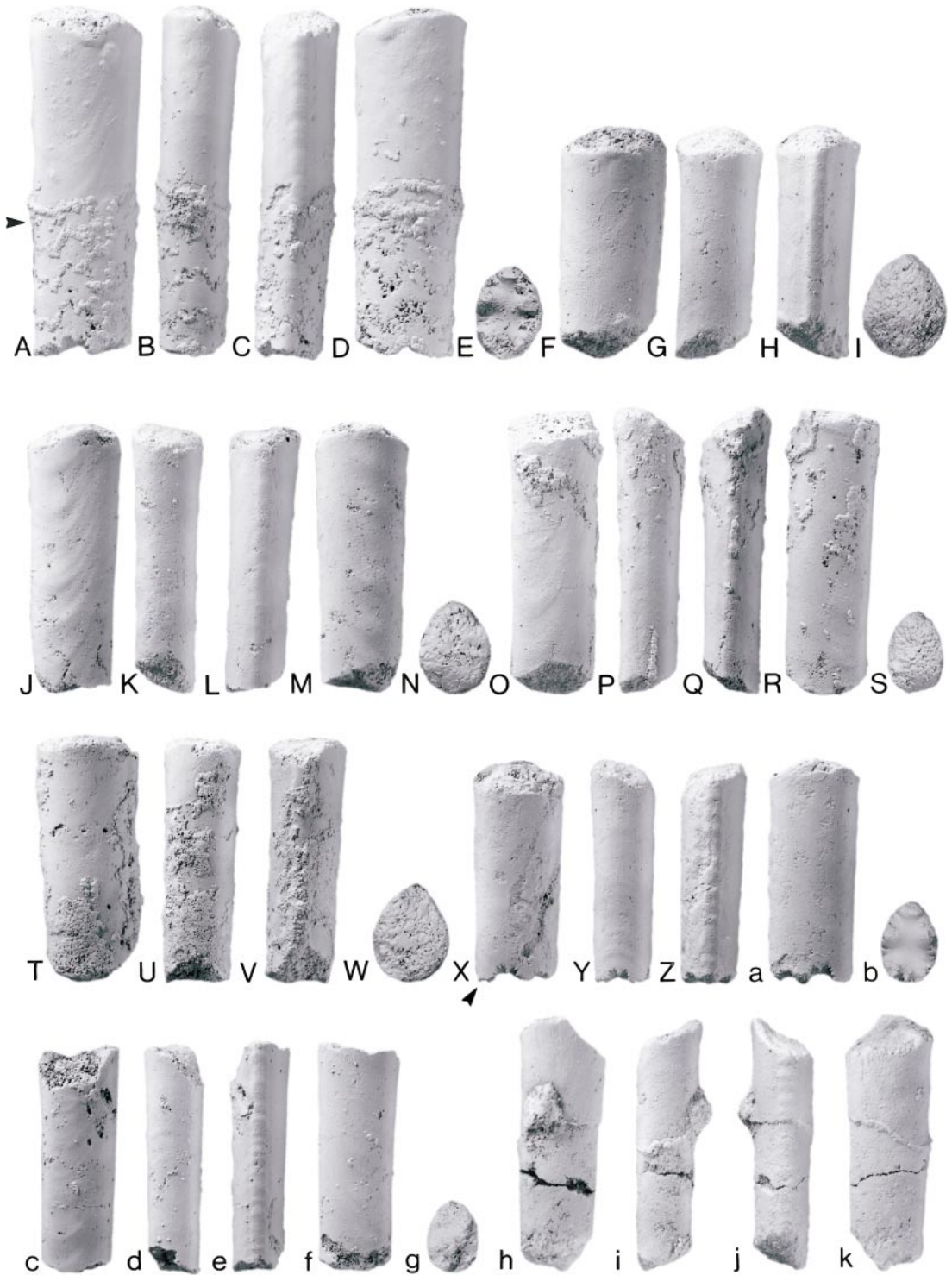


Fig. 31. *Eubaculites latecarinatus* (Brunnschweiler, 1966). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. A-E. AMNH 47273. A, Right lateral; B, dorsal; C, ventral; D, left lateral; E, whorl cross section

adoral ends, respectively (fig. 31O–S). The ratio of whorl width to height at the adoral end is 0.74. The venter is narrow and flat and set off by a narrow ventrolateral furrow. Ribs are very weak on the dorsum and show a strong adoral projection. The inner one-half of the flanks bear weak, crescentic ribs with very faint riblets or striae between them. The distance between consecutive ribs is approximately 9 mm, yielding a rib index of 2.5. Ribs slant strongly forward on the outer one-half of the flanks. The venter is covered with barely perceptible ribs, although this may be due in part to poor preservation. The spacing between consecutive ribs is 3.5 mm, yielding a rib index of 5.

AMNH 47422 is a fragment of a body chamber 39.6 mm long with whorl heights of 15.1 mm and 16.4 mm at the adapical and adoral ends, respectively (fig. 31T–W). The ratio of whorl width to height at the adoral end is 0.74. The outer flanks are nearly smooth with very faint, low crescentic ribs; the rib index is 3. The venter, which is set off by a deep ventrolateral groove, is mostly covered by matrix.

AMNH 47425 is a fragment of the adoral part of a phragmocone and the adapical part of the body chamber (fig. 31X–Z, a,b). It is 36.0 mm long with some iridescent shell material on the dorsum. The whorl heights at the adapical and adoral ends are 13.5 mm and 14.8 mm, respectively. The ratio of whorl width to height at the adoral end is 0.71. The angle of taper is 2.4° . The dorsum, especially on the adapical end, is covered with faint, low, strongly convex ribs. The two most adapical ribs are approximately 3 mm apart. The inner flanks are smooth with only a slight trace of crescentic ribs on the dorsolateral margin on the right side near the adapical end. The ribs strengthen slightly and

slant steeply forward on the outer flanks. The venter is covered with swollen transverse ribs with a rib index of 6.

AMNH 47426 is a fragment of a body chamber 36.4 mm long with whorl heights of 12.0 mm and 13.2 mm at the adapical and adoral ends, respectively (fig. 31c–g). The ratio of whorl width to height at the adoral end is 0.71. The inner flanks are nearly smooth with very faint crescentic ribs with a rib index of approximately 4. The narrow tabulate venter is covered with transverse to slightly convex ribs with a rib index of 8.

AMNH 47408 is 69.3 mm long and consists of the adoral part of a phragmocone and the adapical part of the body chamber (fig. 32A–E). The whorl heights at the adapical and adoral ends are 10.9 mm and 14.8 mm, respectively. The ratio of whorl width to height at the adoral end is 0.70. The angle of taper is 4.0° . The venter is set off by a faint ventrolateral furrow. Ribs cross the dorsum with a slight adoral projection. They swing backward on the dorsolateral margin and are strongly concave on the inner one-half of the flanks. They are very weak and closely spaced on most of the specimen until a whorl height of 14.4 mm, where they become node-like and more widely spaced. The distance between the two most adoral nodes is 11 mm, yielding a rib index of 2. Ribs slant steeply forward at an angle of approximately 20° on the outer one-half of the flanks. The venter is covered with faint transverse ribs spaced at distances of 1–2 mm so that the rib index is approximately 10.

MAPS A2053c5 is the adapical part of a body chamber 47.2 mm long with whorl heights of 11.2 mm and 13.8 mm at the adapical and adoral ends, respectively (fig. 32F–J). The whorl section at the adoral end is compressed ovoid with a ratio of whorl width

←

at adoral end. **F–I.** AMNH 47414. **F**, Right lateral; **G**, dorsal; **H**, ventral; **I**, whorl cross section at adoral end. **J–N.** AMNH 47411. **J**, Right lateral; **K**, dorsal; **L**, ventral; **M**, left lateral; **N**, whorl cross section at adoral end. **O–S.** AMNH 47417. **O**, Right lateral; **P**, dorsal; **Q**, ventral; **R**, left lateral; **S**, whorl cross section at adoral end. **T–W.** AMNH 47422. **T**, Right lateral; **U**, dorsal; **V**, ventral; **W**, whorl cross section at adoral end. **X–Z, a, b.** AMNH 47425. **X**, Right lateral; **Y**, dorsal; **Z**, ventral; **a**, left lateral; **b**, whorl cross section at adoral end. **c–g.** AMNH 47426. **c**, Right lateral; **d**, dorsal; **e**, ventral; **f**, left lateral; **g**, whorl cross section at adoral end. **h–k.** AMNH 47406. **h**, Right lateral; **i**, dorsal; **j**, ventral; **k**, left lateral. All figures are $\times 1$.

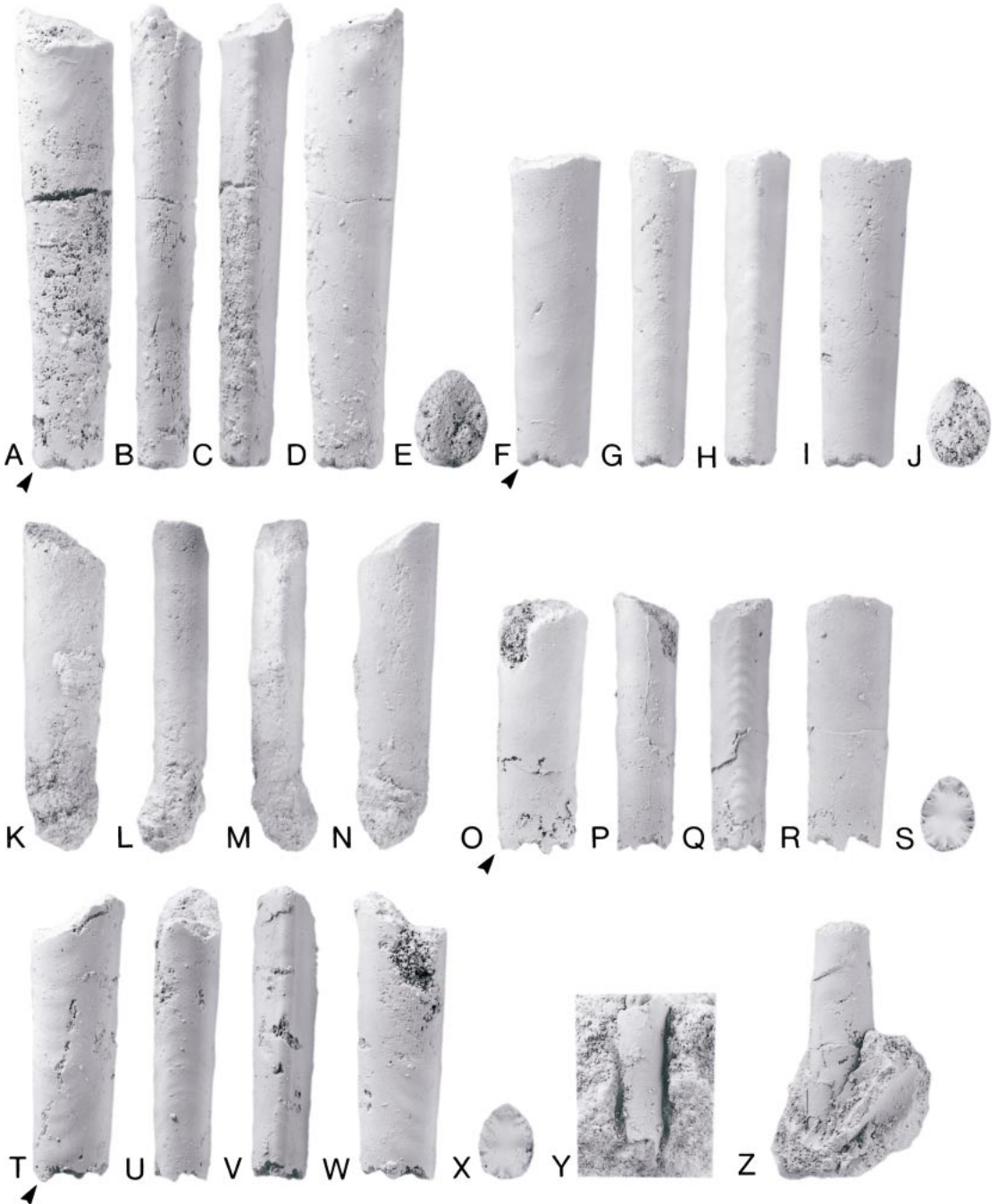


Fig. 32. *Eubaculites latecarinatus* (Brunnschweiler, 1966). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–E.** AMNH 47408. **A**, Right lateral; **B**, dorsal; **C**, ventral; **D**, left lateral; **E**, whorl cross section at adoral end. **F–J.** MAPS A2053c5. **F**, Right lateral; **G**, dorsal; **H**, ventral; **I**, left lateral; **J**, whorl cross section at adoral end. **K–N.** AMNH 47405. **K**, Right lateral; **L**, dorsal; **M**, ventral; **N**, left lateral. **O–S.** AMNH 47407. **O**, Right lateral; **P**, dorsal; **Q**, ventral; **R**, left lateral; **S**, whorl cross section at adoral end. **T–X.** AMNH 47419. **T**, Right lateral; **U**, dorsal; **V**, ventral; **W**, left lateral; **X**, whorl cross section at adoral end. **Y.** AMNH 47404, partly in nodule. **Z.** AMNH 50544, partly in nodule. All figures are $\times 1$.

TABLE 7
Measurements of *Eubaculites latecarinatus* (Brunnschweiler, 1966)^a

Specimen	L (mm)	WW/WH	Taper angle (degrees)	Rib index	
				Flanks	Venter
AMNH 47273	56.4	0.66	2.8	7	6
AMNH 47407	38.0	0.79	3.2	3	7
AMNH 47408	69.3	0.70	4.0	—	10
AMNH 47411	43.4	0.76	3.4	4	7
AMNH 47414	38.0	—	3.6	S	S
AMNH 47417	45.7	0.74	1.4	2.5	5
AMNH 47419	43.2	—	3.4	6	S
AMNH 47422	39.6	0.74	—	3	—
AMNH 47425	36.0	0.71	2.4	S	6
AMNH 47426	36.4	0.71	3.0	4	8
AMNH 47432	36.3	0.74	1.6	3	6
AMNH 47485	29.6	0.74	—	S	S
AMNH 47500	33.0	0.73	3.2	4	5
AMNH 47510	35.6	0.73	1.8	S	7
MAPS A2053c3	48.2	0.71	1.8	S	6
MAPS A2053c4	40.7	0.72	2.8	S	8
MAPS A2053c5	47.2	0.72	3.6	3	5

^aSee table 6 for explanation of abbreviations.

to height of 0.72. The angle of taper is 3.6°. The inner flanks are ornamented with very faint, asymmetrically crescentic ribs with a rib index of 3. The venter bears faint transverse ribs with a rib index of 5.

AMNH 47407 is a fragment consisting of the adoral part of a phragmocone and adapical part of the body chamber (fig. 32O–S). It is 38.0 mm long with whorl heights of 11.6 mm and 12.2 mm at the adapical and adoral ends, respectively. The ratio of whorl width to height at the adoral end is 0.79. The angle of taper is 3.2°. There are very faint crescentic swellings on the inner flanks spaced at distances of approximately 7.0 mm, yielding a rib index of 3. The narrow tabulate venter is covered with conspicuous swollen ribs that arch slightly forward. They are evenly spaced at distances of approximately 2 mm, yielding a rib index of 7.

AMNH 47419 is a fragment of a body chamber with some iridescent shell on the dorsum and last septum (fig. 32T–X). It is 43.2 mm long with whorl heights of 11.7 mm and 14.9 mm at the adapical and adoral ends, respectively. The angle of taper is 3.4°. Ribs cross the dorsum with a moderately strong adoral projection. The inner one-half of the flanks are nearly smooth with very weak,

broad, crescentic ribs with a rib index of approximately 6. The venter is nearly smooth with very faint ribs.

MAPS A2053c4 (not illustrated) is a completely septate fragment 40.7 mm long with whorl heights of 16.0 mm and 18.0 mm at the adapical and adoral ends, respectively. The whorl section at the adoral end is compressed ovoid with a ratio of whorl width to height of 0.72. The inner flanks are smooth although the specimen is not well preserved. The venter is flat and relatively broad and is covered with faint, transverse ribs with a rib index of approximately 8.

MAPS A2053c3 (not illustrated) is a fragment of the adapical part of a body chamber 48.2 mm long with whorl heights of 11.4 mm and 16.1 mm at the adapical and adoral ends, respectively. The whorl section at the adoral end is compressed ovoid with a ratio of whorl width to height of 0.71. The dorsum is flat and the dorsolateral shoulder is fairly sharply rounded. The inner flanks are broadly rounded with maximum width at mid-whorl height. The outer flanks converge steeply to the venter, which is bordered by a shallow longitudinal groove. The ventrolateral shoulder is fairly sharply rounded and the venter is flat. The dorsum bears faint con-

vex folds, the flanks are smooth, and the venter is covered with broad, transverse ribs with a rib index of 6.

AMNH 47432 (not illustrated) is a fragment of a body chamber 36.3 mm long with whorl heights of 13.9 mm and 14.6 mm at the adapical and adoral ends, respectively. The ratio of whorl width to height at the adoral end is 0.74. There are broad crescentic ribs on the dorsal one-half of the flanks with a rib index of 3. The tabulate venter is covered with swollen, transverse ribs with a rib index of 6.

AMNH 47500 (not illustrated) is a fragment of a body chamber 33.0 mm long with whorl heights of 10.2 mm and 12.1 mm at the adapical and adoral ends, respectively. The ratio of whorl width to height at the adoral end is 0.73. The dorsum is covered with weak adorally projected folds. A low ridge occurs along the midline of the dorsum. Weak, asymmetrically crescentic ribs cover the dorsal one-half of the flanks. Smaller riblets appear between two of these ribs; the rib index is 4. The venter is narrow and broadly rounded and is covered with faint, transverse ribs with a rib index of approximately 5.

Parts of the sutures of two specimens (AMNH 47493 and 47501) are illustrated in Figure 30C, D and show a bifid E/L, a narrow, bifid L, a broad, bifid L/U, a bifid U, and a narrow I.

DISCUSSION: This species is characterized by weak to no ornament on the flanks, and a narrow, tabulate venter covered with ribs, producing a serrated appearance. Klinger and Kennedy (1993, 2001) described this species from Zululand and Natal, South Africa, where specimens attain a much larger size than those from New Jersey. These authors also noted the presence of smooth specimens of *Eubaculites carinatus* that are identical to *E. latecarinatus*, but argued that populations of these two species are sufficiently distinct to separate them. The two species are not equally abundant in Zululand, with *E. latecarinatus* more common than *E. carinatus*. This disparity is also reflected in our sample; *E. latecarinatus* is 20% more abundant than *E. carinatus*. However, all of our specimens are internal molds and the absence of ornamentation, interpreted as indicating *E. latecarinatus*, may be a reflection of poor pres-

ervation, implying that the abundance of *E. latecarinatus* may be overestimated. In addition, our specimens are fragmentary, making it difficult to distinguish between ontogenetic and intraspecific variation (see Tsujino et al., 2003).

OCCURRENCE: This species occurs in New Jersey in the upper part of the New Egypt Formation and as reworked material at the base of the Hornerstown Formation, near Eatontown, northeastern Monmouth County; in the top of the New Egypt Formation in the Crosswicks Creek Basin, southwestern Monmouth County (Landman et al., in prep. b); and in the top of the Tinton Formation and as reworked material at the base of the Hornerstown Formation near Freehold, central Monmouth County (Landman et al., in prep. a). This species is also known from the Severn Formation, Prince Georges County, Maryland (Kennedy et al., 1997), and Kent County, Maryland (Landman et al., 2004). Klinger and Kennedy (2001) reported this species from the Maastrichtian of Zululand, South Africa, the offshore Alphonse Group, south India, Madagascar, and Western Australia.

Eubaculites sp.

Figure 33A–T

Compare: *Eubaculites latecarinatus* (Brunnenschweiler, 1966). Kennedy et al., 1997: 20, figs. 15A–D, K, L, 16G, H, 19.

MATERIAL: There are four specimens (MAPS A2053c1, -2, AMNH 47160, and 47161) from AMNH loc. 3346 from the upper part of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation, Parkers Creek, near Eatontown, northeastern Monmouth County. All of the specimens are internal molds of parts of body chambers.

DESCRIPTION: MAPS A2053c1 is a large piece of a body chamber 68.4 mm long (fig. 33A–E). The whorl heights at the adapical and adoral ends are 20.2 mm and 24.1 mm, respectively. The whorl section is better preserved at the adapical end and is compressed ovoid with a ratio of whorl width to height of 0.68. The angle of taper is 1.6°. The dorsum is nearly flat and the dorsolateral shoulder is fairly abruptly rounded. The inner

flanks are broadly rounded and nearly parallel and the outer flanks converge toward the venter. There is a shallow longitudinal depression that borders the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is narrow and broadly rounded. The inner flanks are covered with weak, concave ribs with a rib index of 14. The venter is ornamented with broad, transverse ribs that show a moderately strong adoral projection; the rib index is approximately 11. The adoral end of this specimen shows two interesting features: (1) the left side shows a bulge, which may represent a healed injury; and (2) the dorsum is flared and projected forward and may represent a mature modification of the aperture.

AMNH 47160 is a fragment of a body chamber 42.4 mm long with whorl heights of 14.9 mm and 16.0 mm at the adoral and adapical ends, respectively (fig. 33F–J). The whorl section at the adoral end is compressed ovoid with a ratio of whorl width to height of 0.67. The venter is demarcated by a shallow, longitudinal depression and is narrow and broadly rounded. There are weak undulations on the dorsum. The flanks on the right side bear two asymmetrically crescentic ribs near the adoral end that are 6 mm apart, so that the rib index is approximately 5. Adapical of these ribs, there is a dent in the flanks, possibly due to an injury. The venter is covered with weak transverse ribs with a rib index of 13.

AMNH 47161 is a fragment of a body chamber 44.4 mm long with whorl heights of 11.6 mm and 14.4 mm at the adapical and adoral ends, respectively (fig. 33K–O). The ratio of whorl width to height at the adoral end is 0.74. The whorl section is ovoid with maximum width at midwhorl height. The dorsum is broadly rounded, the inner flanks are divergent and nearly flat, and the outer flanks gradually converge to the venter. The venter is narrow and broadly rounded and is covered with barely perceptible, closely spaced ribs. The flanks are smooth except for one thin crescentic rib.

MAPS A2053c2 is a body chamber fragment 56.3 mm long with whorl heights of 15.8 mm and 19.5 mm at the adapical and adoral ends, respectively (fig. 33P–T). The whorl section at the adoral end is compressed

ovoid with a ratio of whorl width to height of 0.70. Most of the flanks are smooth but weak ribs slant markedly forward on the outer flanks at an angle of 20°. The venter is narrow and broadly rounded and bears transverse ribs. They are irregularly spaced with a rib index of approximately 8.

DISCUSSION: These specimens resemble *Eubaculites latecarinatus* in their oval whorl section with narrow venter, and weak ornament, but differ in having a broadly rounded rather than tabulate venter. In this respect, these specimens are reminiscent of *Eubaculites* sp. illustrated by Kennedy et al. (2000: fig. 8I–T) from the lower part of the Navesink Formation in a tributary on the west side of Crosswicks Creek, south of Allentown, southwestern Monmouth County, New Jersey. However, our specimens are not as coarsely ornamented. The specimen of *Baculites* sp. illustrated by Kennedy et al. (2000: fig. 7A–C) from the top of the New Egypt Formation at the Inversand Pit, Gloucester County, New Jersey, also bears some resemblance to our material.

OCCURRENCE: AMNH loc. 3346 from the upper part of the New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey.

SUPERFAMILY SCAPHITACEAE GILL, 1871

FAMILY SCAPHITIDAE GILL, 1871

SUBFAMILY SCAPHITINAE GILL, 1871

Genus *Discoscaphites* Meek, 1871

TYPE SPECIES: *Ammonites conradi* Morton, 1834: 39, pl. 16, fig. 3, by original designation.

Discoscaphites iris (Conrad, 1858)

Figures 34, 35, 36A–H, K–Q, S–Z, l–p, 37A–I, 38, 39A–P, 41A–D

Scaphites iris Conrad, 1858: 335, pl. 35, fig. 23.
Scaphites iris Conrad. Whitfield, 1892: 265, pl. 44, figs. 4–7.

Discoscaphites iris (Conrad). Stephenson, 1955: 134, pl. 23, figs. 23–30.

Discoscaphites iris (Conrad, 1858). Kennedy and Cobban, 2000: 183, fig. 5, pl. 3, figs. 3–35.

TYPE: The holotype is the original illustrated in Conrad, 1858: 335, pl. 35, fig. 23,

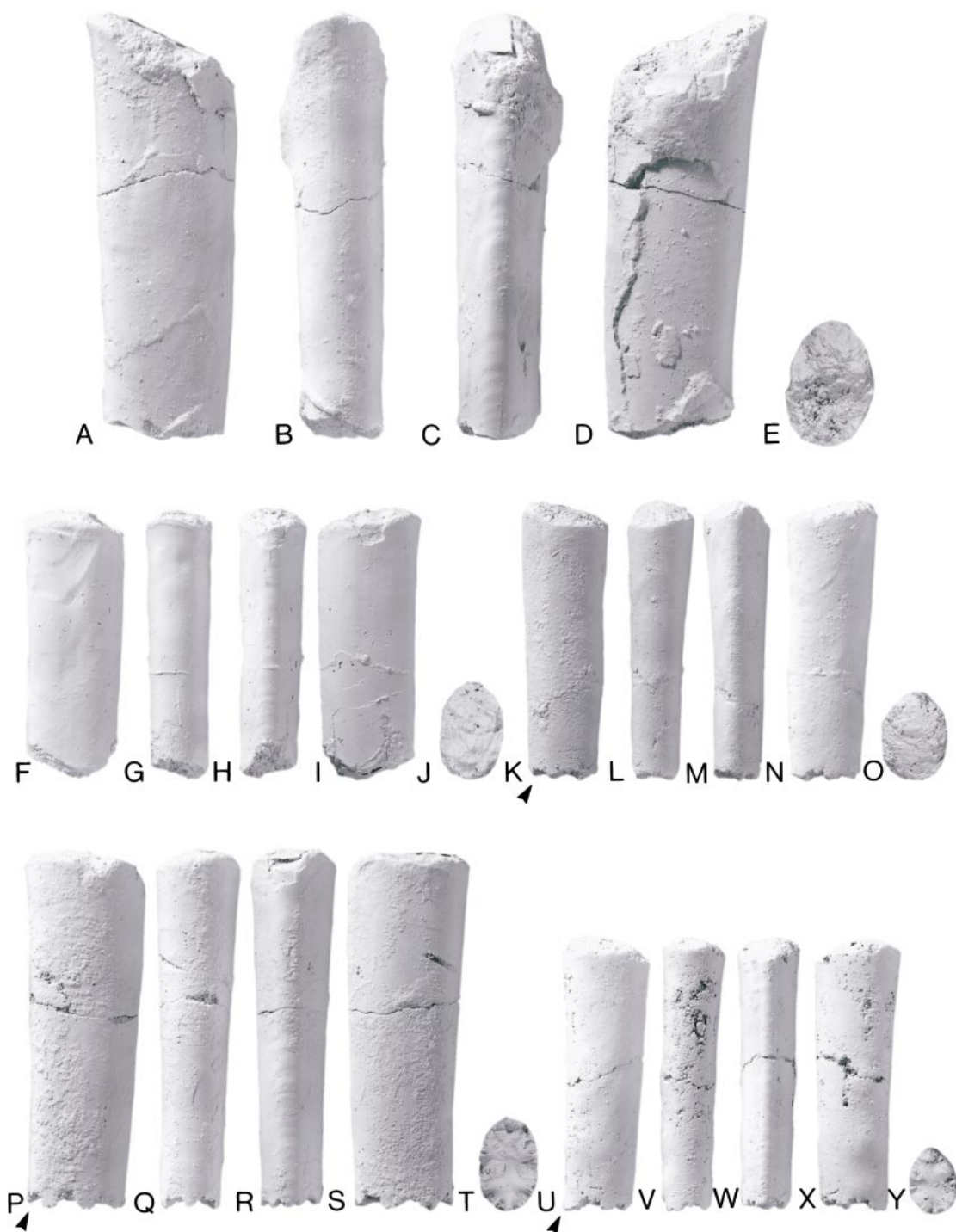


Fig. 33. A–T. *Eubaculites* sp. Upper New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, AMNH loc. 3346, northwest of Eatontown, Monmouth County, New Jersey. A–E. MAPS A2053c1. A, Right lateral; B, dorsal; C, ventral; D, left lateral; E, whorl cross section at apical end. F–J. AMNH 47160. F, Right lateral; G, dorsal; H, ventral; I, left lateral; J, whorl cross

labeled ANSP 50989, from the bluffs of Owl Creek, Tippah County, Mississippi. It is a partly crushed, fairly robust specimen, missing part of the phragmocone and hook and is attached to a piece of matrix. It is probably a microconch, but this is difficult to confirm because of the crushing. It retains part of its original, iridescent shell. The body chamber bears four rows of tubercles with the umbilicolateral tubercles being the most prominent. These tubercles show steep adapical sides and more gently sloping adoral sides.

MATERIAL: All of our specimens are from the top of the New Egypt Formation and base of the Hornerstown Formation, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey. They are all internal molds and most of them are pieces of body chambers. The majority of specimens are from two clusters (1 and 2). Cluster 1 consists of a hardened chunk of chocolate brown clay peppered with large, green glauconite grains and contains 68 specimens, 28 of which are definitely identified as *Disco-scaphites iris* (AMNH 47332, 47336, 47337, 47339, 47341–47343, 47345–47349, 47351–47361, 51057–51059, 51061, and 51062). The rest of the specimens are fragments. Some of these are difficult to identify at all whereas others hint at different species. Most of the specimens of *D. iris* in cluster 1 are slender with weak tubercles. Only one specimen (AMNH 51059) is nearly whole but lacks the innermost whorls. AMNH 47360 is the next most complete specimen and consists of one-third whorl of an adult phragmocone and the complete body chamber. Of the 20 specimens that can be divided into macroconchs and microconchs, there are an almost equal number of each dimorph: 11 macroconchs and 9 microconchs. Cluster 2 consists of five specimens, all pieces of robust body chambers of microconchs (MAPS A2060a2, 3, AMNH 47308, 47363, and 51055).

DESCRIPTION: Like other scaphites, this species is strongly dimorphic. Dimorphs are distinguished by the shape of the adult body chamber. In side view, the umbilical shoulder of the body chamber is straight in macroconchs whereas it is curved in microconchs. Macroconchs are slightly larger than microconchs, but the size ranges of the dimorphs overlap. This species is characterized by four rows of tubercles: an umbilical or umbilicolateral row, depending on its position relative to the umbilical shoulder, a midflank row, and inner and outer ventrolateral rows. The umbilicolateral tubercles are the most prominent. The number of outer ventrolateral tubercles is equal to or slightly greater than the number of inner ventrolateral tubercles. As in other scaphite species, there is a range in variation from robust specimens with prominent tubercles (fig. 34A–D) to slender specimens with weak tubercles (fig. 35A–D). This variation is partly expressed in the ratio of whorl width to height at midshaft (table 8). We first describe the coarser specimens within each dimorph.

MACROCONCH DESCRIPTION

The most robust specimen is AMNH 51060, an internal mold, 38.6 mm in maximum diameter, consisting of a phragmocone and one-half of the adult body chamber (fig. 34A–D). The phragmocone is 30.9 mm in diameter. It is tightly coiled with a tiny umbilicus approximately 1.5 mm in diameter; the ratio of umbilical diameter to phragmocone diameter is 0.05. In side view, the venter of the phragmocone passes smoothly into the venter of the body chamber. Only the posterior one-half of the body chamber is preserved. The umbilical wall of the body chamber shows a slight bulge at approximately midshaft. There is only a small gap between the body chamber and the phragmocone.

←

section at adapical end. **K–O.** AMNH 47161. **K,** Right lateral; **L,** dorsal; **M,** ventral; **N,** left lateral; **O,** whorl cross section at adoral end. **P–T.** MAPS A2053c2. **P,** Right lateral; **Q,** dorsal; **R,** ventral; **S,** left lateral; **T,** whorl cross section at adapical end. **U–Y.** *Eubaculites carinatus* (Morton, 1834), AMNH 47159, same locality as A–T. **U,** Right lateral; **V,** dorsal; **W,** ventral; **X,** left lateral; **Y,** whorl cross section at adapical end. All figures are $\times 1$.

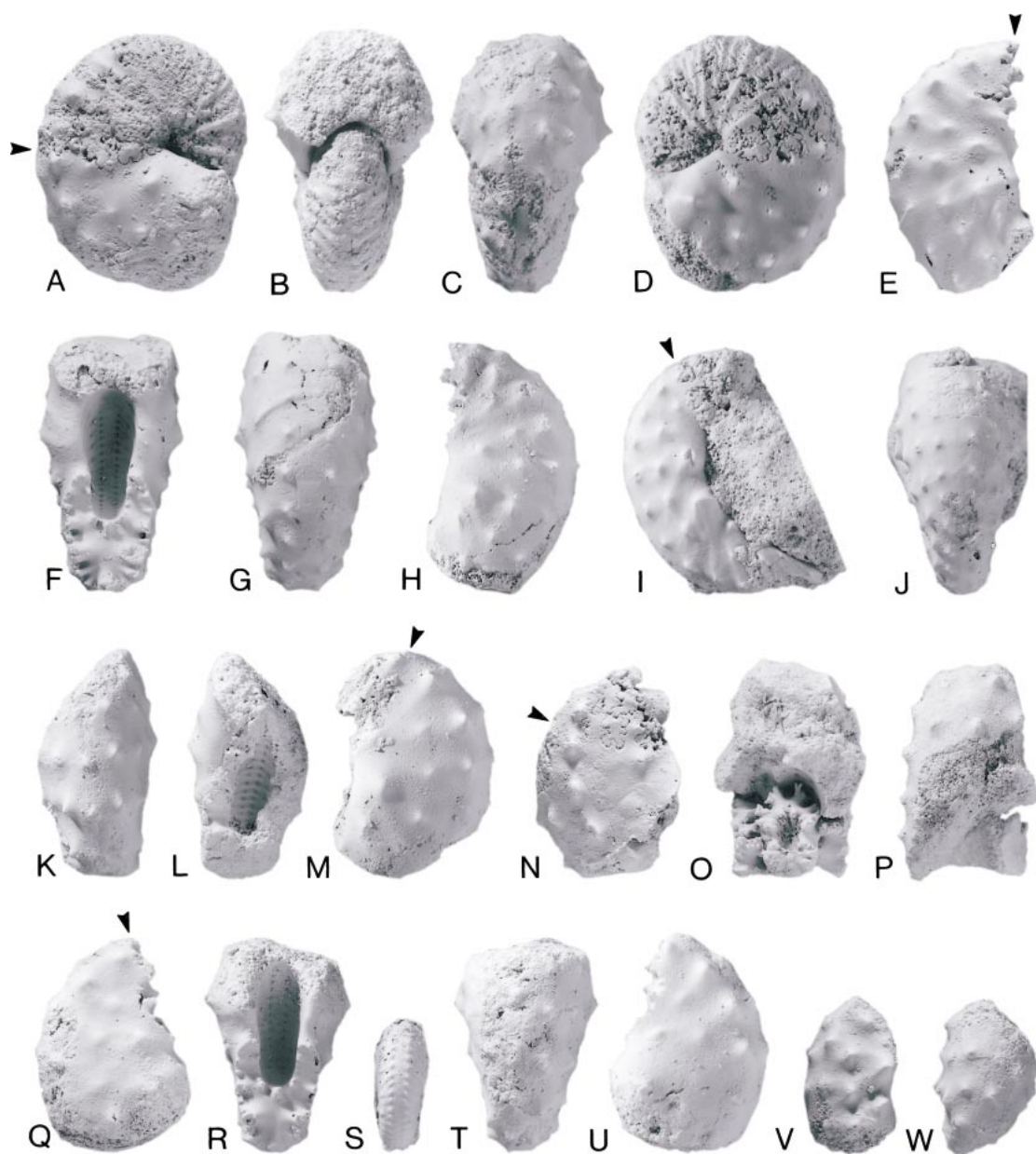


Fig. 34. *Discoscaphites iris* (Conrad, 1858). Uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–D.** AMNH 51060, robust macroconch. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–H.** MAPS A2060a1, robust macroconch. **E**, Right lateral; **F**, apertural; **G**, ventral; **H**, left lateral. **I, J.** MAPS A2060a4, robust microconch with matrix still attached. **I**, Right lateral; **J**, ventral. **K–M.** AMNH 47366, coarsely ornamented macroconch. **K**, Ventral; **L**, apertural; **M**, left lateral. **N–P.** AMNH 47365, macroconch. **N**, Right lateral; **O**, apertural; **P**, ventral. **Q–U.** AMNH 47367, macroconch with peel of inner whorls. **Q**, Right lateral; **R**, apertural; **S**, peel of inner whorls; **T**, ventral; **U**, left lateral. **V, W.** AMNH 47372, dimorph indeterminate. **V**, Right lateral; **W**, ventral. All figures are $\times 1$.

The phragmocone is robust; the ratio of whorl width to height is 0.98 at the adapical end and decreases to 0.87 at the ultimate septum. The whorl section at the ultimate septum is compressed ovoid with maximum width at one-quarter whorl height. The umbilical wall is steep and inclined outward and the umbilical shoulder is gently rounded. In intercostal section, the flanks are broadly rounded and converge to the ventrolateral shoulder. The ventrolateral shoulder is sharply rounded and the venter is nearly flat.

The whorl section at approximately midshaft is robust with a ratio of 0.97 in both costal and intercostal section. The umbilical wall is steep and convex and the umbilical shoulder is broadly rounded. In costal section, the inner flanks are flat and inclined outward, attaining maximum width at one-quarter whorl height, the midflanks are nearly flat, and the outer flanks, between the inner and outer ventrolateral tubercles, are flat and converge toward the venter. In intercostal section, the inner flanks are well rounded and inclined outward, the midflanks are very broadly rounded, and the outer flanks are flat and converge toward the venter. The ventrolateral shoulder is sharply rounded and the venter is nearly flat.

Details of the ornament are better preserved on the left side of the specimen. On the adapical end of the phragmocone, relatively strong primary ribs are rectiradial to slightly rursiradial on the umbilical shoulder and inner flanks. They are moderately widely spaced and slightly raised at one-quarter whorl height, which is the site of future umbilicolateral tubercles. Ribs are straight and rectiradial on the midflanks. Branching and intercalation occur at one-third whorl height. One primary rib shows a faint bulla at the position where midflank tubercles eventually develop, but these are hardly discernable at this point. Intercalation and branching occur at the site of the inner ventrolateral tubercles, which occur on the primary ribs and possibly on the secondary ribs, but it is difficult to establish this because of poor preservation. The ribs on the outer flanks are broad and gently inclined toward the venter. Each rib bears a prominent outer ventrolateral tubercle, which is matched on the other side of the venter. These tubercles are evenly spaced

at distances of approximately 2 mm. Ribs on the venter are faint, straight, and swollen, joining pairs of tubercles. There are approximately 5 ribs/cm on the venter.

Toward the adoral end of the phragmocone, the ribs become less distinct, possibly because of poor preservation. The primary ribs swell into umbilicolateral tubercles on the inner flanks; the two most adoral tubercles are approximately 4.5 mm apart on the left side. A midflank tubercle also appears at the ultimate septum. Two inner ventrolateral tubercles are spaced approximately 7 mm apart near the base of the body chamber. The tubercles of the outer ventrolateral row become more widely spaced adorally. The distance between tubercles on the adoral end of the phragmocone is approximately 7 mm whereas the distance between tubercles on the adapical end is 2 mm. Near the base of the body chamber, these tubercles alternate on either side of the ventral margin.

The ornament on the body chamber consists of four rows of tubercles on low, broad, convex ribs. Tubercles of progressively more outward rows are disposed more adapically. There are two umbilicolateral tubercles preserved on the left side spaced approximately 7 mm apart, of which the most adoral tubercle is the most prominent one on the specimen. Two concave ribs appear to branch from it. The midflank row is more subdued and consists of four tubercles (including the one at the ultimate septum), which are spaced 5 mm apart at midshaft. The inner ventrolateral tubercles, of which there are four preserved (including the one at the ultimate septum), are evenly spaced at distances of 6 mm, and are slightly clavate. These three rows are equally distant from each other. In contrast, the outer ventrolateral row is closer to the inner ventrolateral row and is more subdued than it. There are four preserved tubercles in this row (including one at the ultimate septum) evenly spaced at distances of approximately 6 mm. As on the adoral part of the phragmocone, the tubercles alternate on either side of the ventral margin. Only part of the last suture is well enough preserved for drawing and shows the typical scaphitid elements U_1 , U_2 , and U_2/L (fig. 41C).

There are several specimens that, although

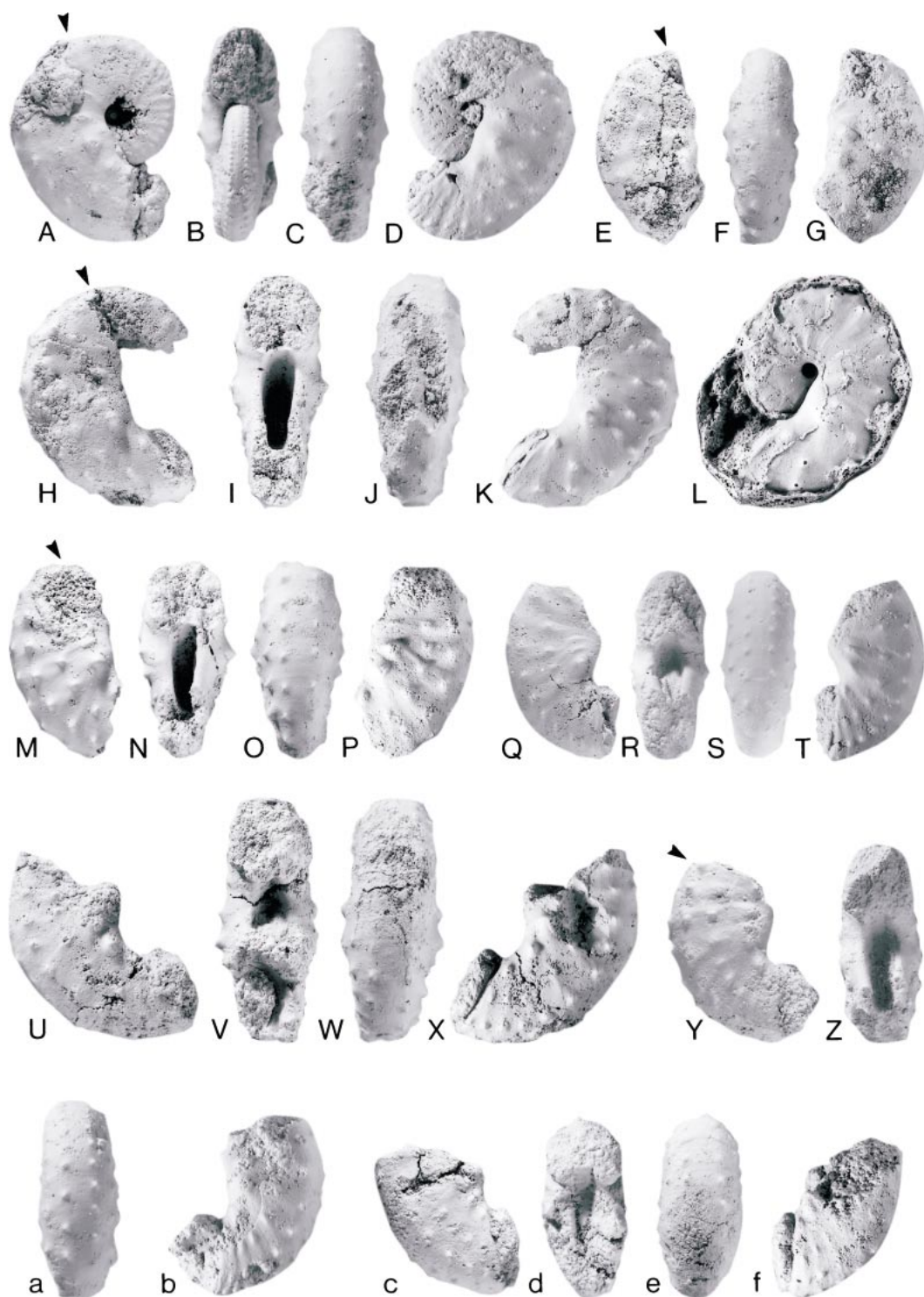


Fig. 35. *Discoscaphites iris* (Conrad, 1858), macroconchs, cluster 1, uppermost New Egypt Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. A–D. AMNH

fragmentary, match AMNH 51060 in their robustness. We describe three specimens. AMNH 47367 is an internal mold of the adapical one-half of a robust body chamber and preserves the impression of part of the phragmocone (fig. 34Q–U). The whorl section at the base of the body chamber is well exposed and is compressed ovoid. The ratio of whorl width to height is 0.74 in intercostal section with maximum width at one-quarter whorl height. The umbilical wall is convex and the umbilical shoulder is fairly sharply rounded. The inner flanks are broadly rounded and inclined slightly outward, the midflanks are nearly flat and gently inclined toward the venter, and the outer flanks are flat and more sharply inclined toward the venter. The ventrolateral shoulder is fairly sharply rounded and the venter is flat. Width expands markedly at midshaft due to the development of a large umbilicolateral tubercle. The ratio of whorl width to height at midshaft is approximately 0.97 in costal section.

The ornament on a peel of a part of the phragmocone shows slightly flexuous prorsiradiate ribs. Ribs are straight on the inner flanks, swelling into weak umbilicolateral bullae, and swing forward on the midflanks; one rib develops into a midflank bulla. Ribs intercalate and bend forward toward the inner ventrolateral tubercles, which are small and bullate. Ribs intercalate again and bend forward toward the outer ventrolateral tubercles of which there are 16 on the peel. These tubercles are approximately evenly spaced at distances of 1.25 mm. They are paired across the venter and are connected by weak ribs, which show a very slight adoral projection. There are approximately 8 ribs/cm on the venter based on an average distance of 1.25 mm between ribs.

The ornament on the body chamber is better preserved on the left side. There are four

rows of tubercles; the largest tubercle is the umbilicolateral tubercle at midshaft. The distances between tubercle rows at midshaft starting with the umbilicolateral row is 7 mm, 6 mm, and 4.75 mm. The distance between outer ventrolateral tubercles on either side of the venter is 5 mm.

AMNH 47365 is an internal mold consisting of a fragment of the adoral part of the phragmocone, and the flanks and part of the venter of the adapical one-quarter of the body chamber (fig. 34N–P). It retains part of the inner whorls showing the ontogenetic transformation from a depressed, kidney-shaped whorl section to a more compressed, rounded whorl section. The body chamber is robust and bears inner and outer ventrolateral and umbilical tubercles; the midflank tubercles are very weak. The last suture of the phragmocone (fig. 41A, B) shows a narrow, asymmetrically bifid first lateral lobe (L). The dorsal suture of the inner whorls shows a narrow, symmetrically trifid lobe.

MAPS A2060a1 is most of a body chamber minus the hook (fig. 34E–H). The umbilical shoulder shows a conspicuous bulge. The whorl section at the base of the body chamber is well preserved. It is compressed ovoid with maximum width at one-third whorl height; the ratio of whorl width to height is 0.81 in costal section. The umbilical wall is steep and convex and the umbilical shoulder is fairly abruptly rounded. The inner flanks are broadly rounded and inclined outward, the midflanks are flat and gently converge toward the venter, and the outer flanks are broadly rounded and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is flat. Width expands more rapidly than height and the ratio of whorl width to height at midshaft is 0.87 in intercostal section and 1.05 in costal section.

←

51059. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–G**. AMNH 47348. **E**, Right lateral; **F**, ventral; **G**, left lateral. **H–L**. AMNH 47360. **H**, Right lateral; **I**, apertural; **J**, ventral; **K**, left lateral; **L**, peel, left lateral. **M–P**. AMNH 47357. **M**, Right lateral; **N**, apertural; **O**, ventral; **P**, left lateral. **Q–T**. AMNH 51061. **Q**, Right lateral; **R**, apertural; **S**, ventral; **T**, left lateral. **U–X**. AMNH 47361. **U**, Right lateral; **V**, apertural; **W**, ventral; **X**, left lateral. **Y–Z**, **a**, **b**. AMNH 51062. **Y**, Right lateral; **Z**, apertural; **a**, ventral; **b**, left lateral. **c–f**. AMNH 47358. **c**, Left lateral; **d**, apertural; **e**, ventral; **f**, left lateral. All specimens $\times 1$.

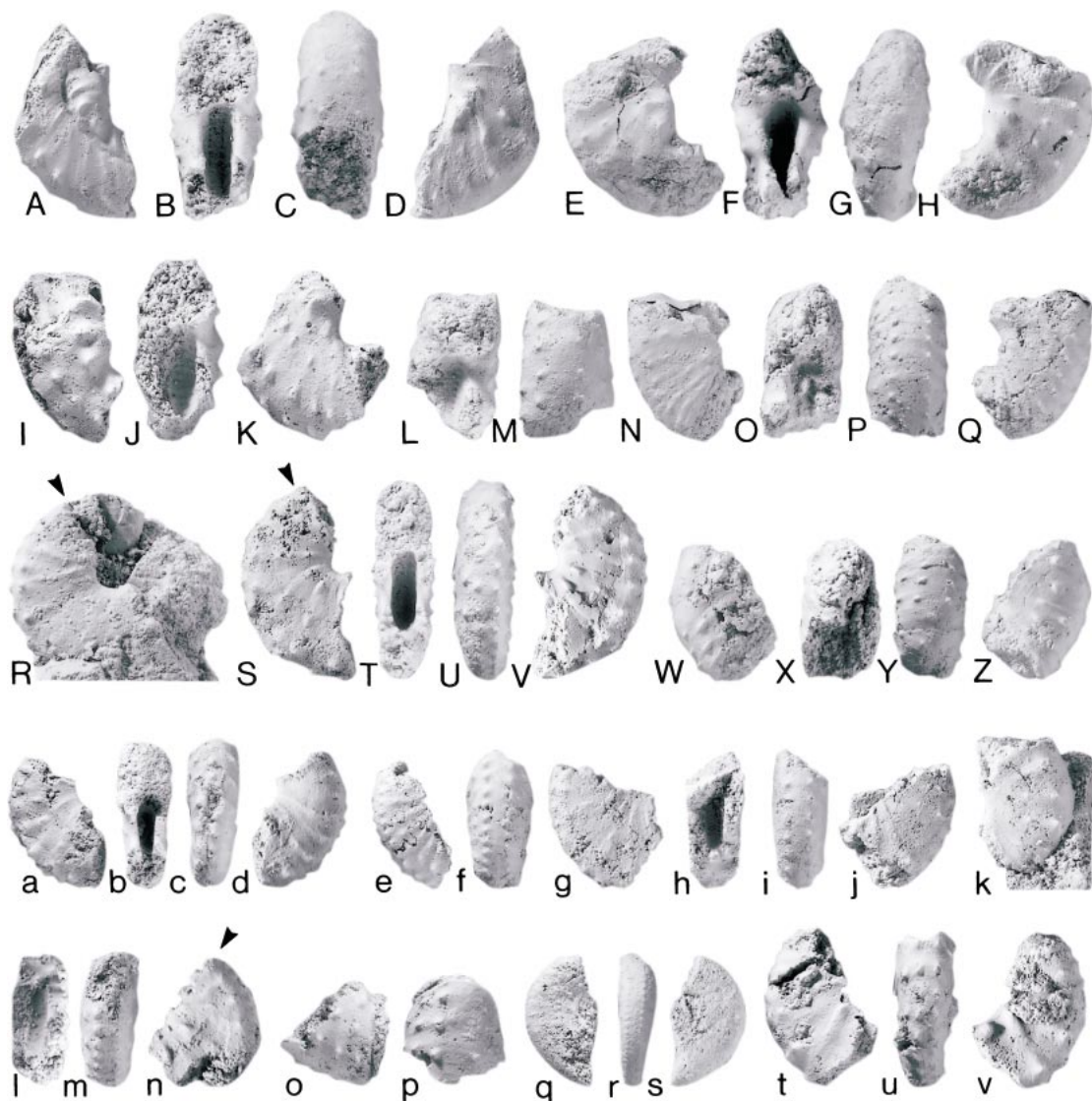


Fig. 36. A–H, K–Q, S–Z, l–p. *Discoscaphites iris* (Conrad, 1858), cluster 1, uppermost New Egypt Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. A–D. AMNH 47355, macroconch with a repaired injury. A, Right lateral; B, apertural; C, ventral; D, left lateral. E–H. AMNH 47351, macroconch. E, Right lateral; F, apertural; G, ventral; H, left lateral. K–M. AMNH 47347, macroconch. K, Right lateral; L, apertural; M, ventral. N–Q. AMNH 47343, dimorph indeterminate. N, Right lateral; O, apertural; P, ventral; Q, left lateral. S–V. AMNH 47349, dimorph indeterminate. S, Right lateral; T, apertural; U, ventral; V, left lateral. W–Z. AMNH 47339, dimorph indeterminate. W, Right lateral; X, apertural; Y, ventral; Z, left lateral. l–n. AMNH 47336, dimorph indeterminate. l, Apertural; m, ventral; n, left lateral. o, p. AMNH 47332, dimorph indeterminate. o, Right lateral; p, ventral. I, J, R, a–k, q–v. *Discoscaphites* spp., same loc. as A–H. I, J. AMNH 47350. I, Right lateral; J, apertural; R. AMNH 51063, right lateral. a–d. AMNH 47328. a, Right lateral; b, apertural; c, ventral; d, left lateral. e, f. AMNH 47324. e, Right lateral; f, ventral. g–j. AMNH 47335. g, Right lateral; h, apertural; i, ventral; j, left lateral. k. AMNH 47391, left lateral. q–s. AMNH 47329. q, Right lateral; r, ventral; s, left lateral. t–v. AMNH 47340. t, Right lateral; u, ventral; v, left lateral. All figures are $\times 1$.

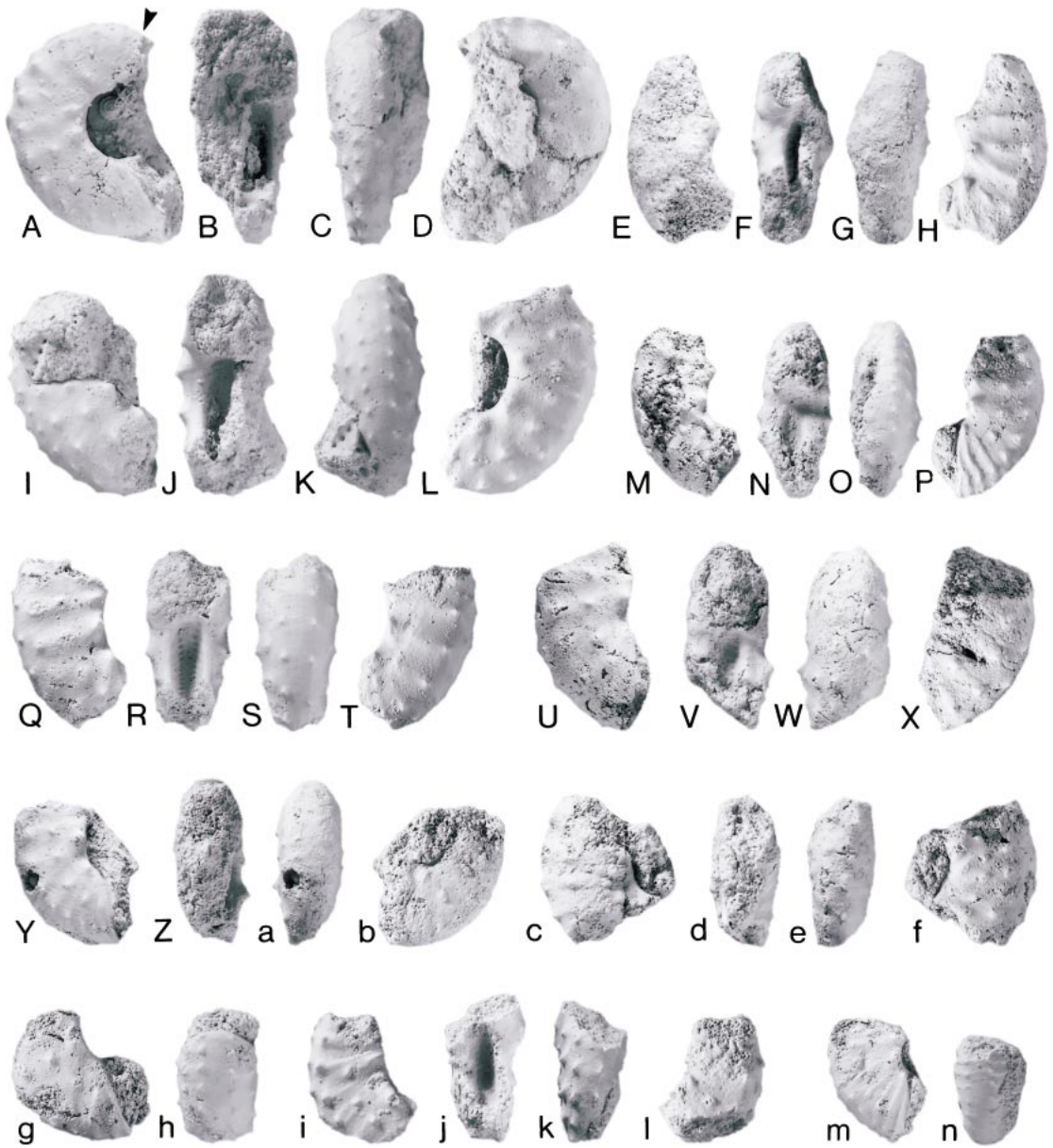


Fig. 37. **A–I.** *Discoscaphites iris* (Conrad, 1858), cluster 1, uppermost New Egypt Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–D.** AMNH 51057, compressed microconch. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–H.** AMNH 47354, microconch. **E**, Right lateral; **F**, apertural; **G**, ventral; **H**, left lateral. **I–L.** AMNH 51058, microconch. **I**, Right lateral; **J**, apertural; **K**, ventral; **L**, left lateral. **M–P.** AMNH 47342, microconch. **M**, Right lateral; **N**, apertural; **O**, ventral; **P**, left lateral. **Q–T.** AMNH 47356, microconch. **Q**, Right lateral; **R**, apertural; **S**, ventral; **T**, left lateral; **U–X.** AMNH 47352, dimorph indeterminate. **U**, Right lateral; **V**, apertural; **W**, ventral; **X**, left lateral. **Y–b.** AMNH 47346, microconch. **Y**, Right lateral; **Z**, apertural; **a**, ventral; **b**, left lateral. **c–f.** AMNH 47353, microconch. **c**, Right lateral; **d**, apertural; **e**, ventral; **f**, left lateral. **g, h.** AMNH 47345, microconch. **g**, Right lateral; **h**, ventral. **i–l.** AMNH 47337, microconch. **i**, Right lateral; **j**, apertural; **k**, ventral; **l**, left lateral. **m, n.** *Discoscaphites* sp., AMNH 47338, same locality as A–I. **m**, Right lateral; **n**, ventral. All figures are $\times 1$.

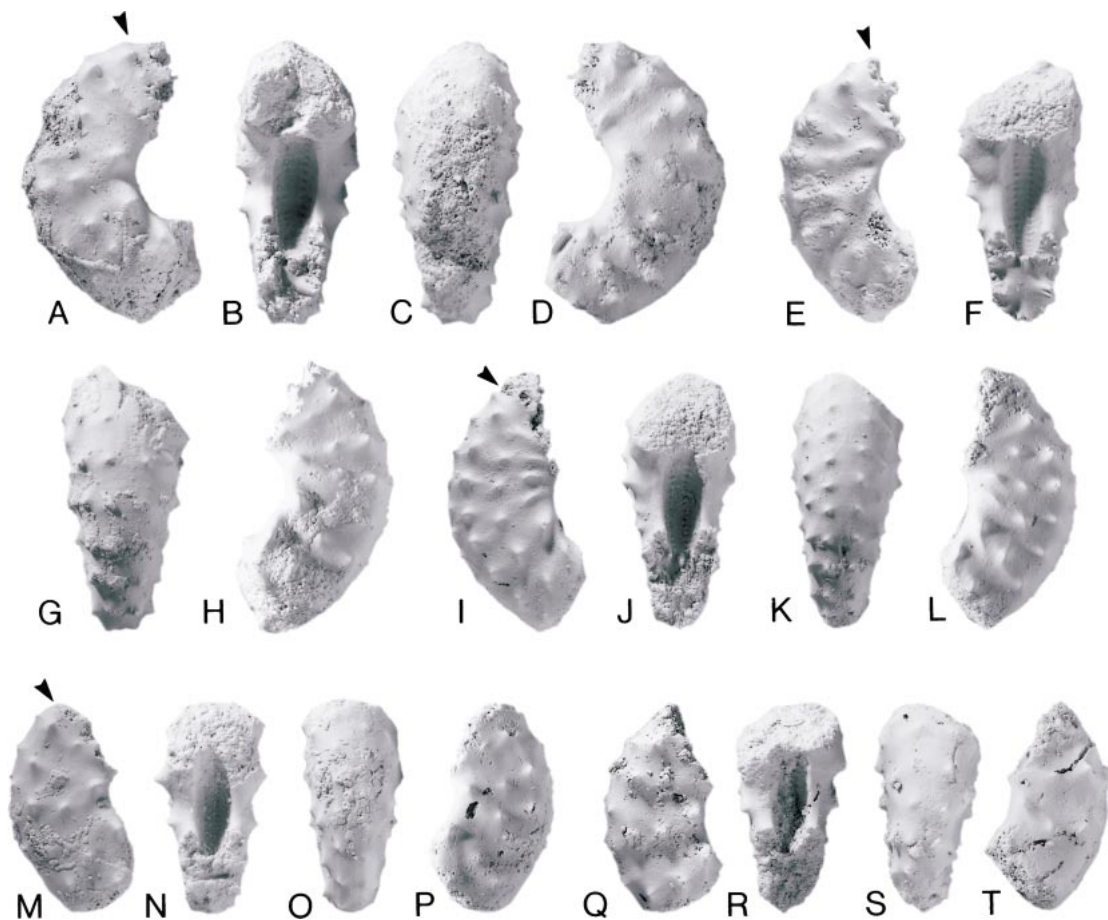


Fig. 38. *Discoscaphites iris* (Conrad, 1858), microconchs, cluster 2, uppermost New Egypt Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–D.** AMNH 47363. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–H.** MAPS A2060a2. **E**, Right lateral; **F**, apertural; **G**, ventral; **H**, left lateral. **I–L.** MAPS A2060a3. **I**, Right lateral; **J**, apertural; **K**, ventral; **L**, left lateral. **M–P.** AMNH 51055. **M**, Right lateral; **N**, apertural; **O**, ventral; **P**, left lateral. **Q–T.** AMNH 47308. **Q**, Right lateral; **R**, apertural; **S**, ventral; **T**, left lateral. All figures are $\times 1$.

There are four rows of tubercles with the umbilicolateral tubercles being the largest and the outer ventrolateral tubercles being the smallest. The distance between umbilicolateral tubercles at midshaft is 6 mm. The midflank tubercles are approximately evenly spaced at distances of 5–6 mm. The inner ventrolateral tubercles are approximately evenly spaced at distance of 5.0–6.5 mm, although they show a slightly wider spacing at midshaft (7–7.5 mm). There are 11 outer ventrolateral tubercles evenly spaced at distances of 5–6 mm. They are matched on either side of the venter. A strong prorsiradiate

rib links an inner and outer ventrolateral tubercle and extends onto the venter on the right side near the adoral end of the specimen. The distance between tubercle rows at midshaft starting with the umbilicolateral row is 5 mm, 6 mm, and 5 mm.

AMNH 51059 is representative of the more slender and more weakly ornamented variants characteristic of cluster 1 (fig. 35A–D). It is a nearly complete macroconch approximately 33.9 mm in diameter. The phragmocone is slightly crushed in on the adoral end on the left side and is missing the innermost whorls. Part of the venter is missing

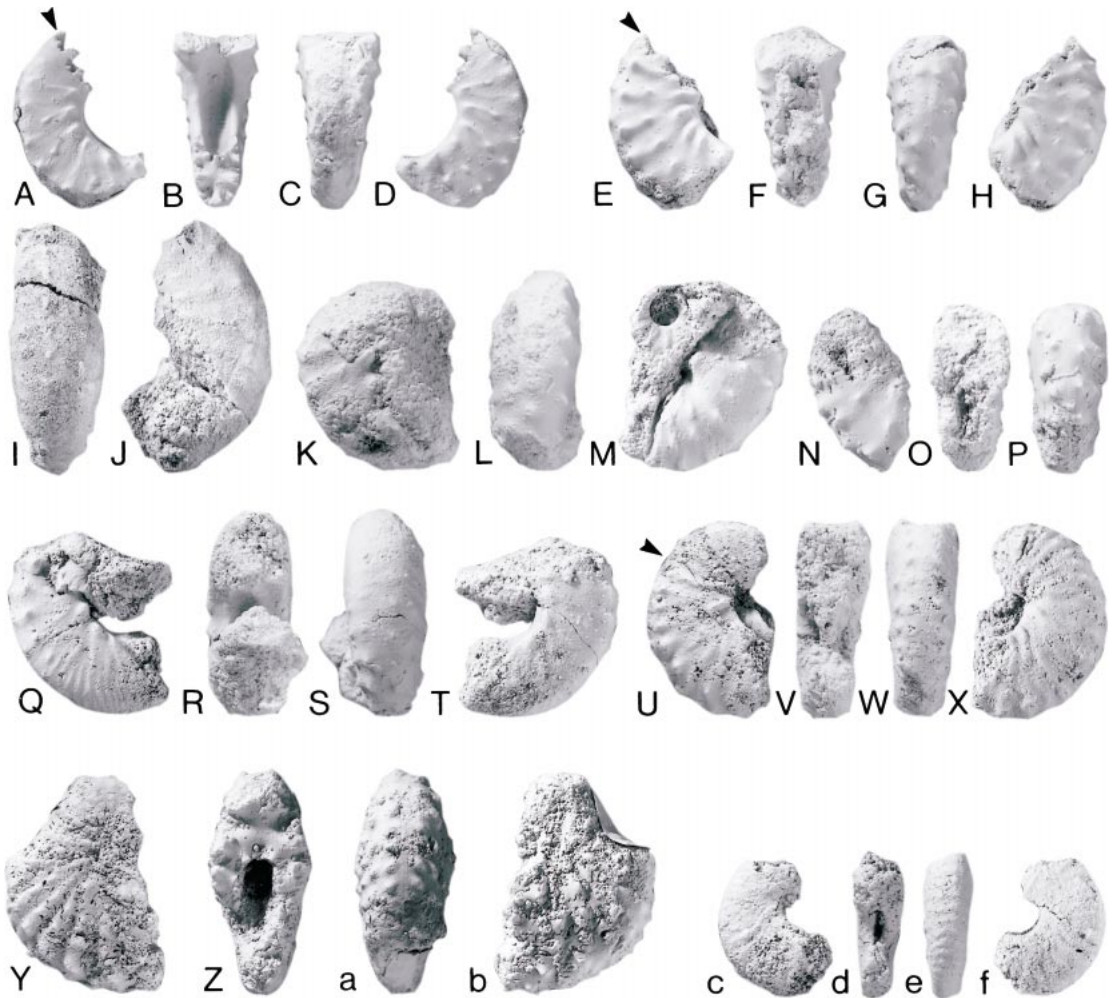


Fig. 39. **A–P.** *Discoscaphites iris* (Conrad, 1858), uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A–D.** AMNH 47105, microconch. **A**, Right lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **E–H.** AMNH 51056, microconch. **E**, Right lateral; **F**, apertural; **G**, ventral; **H**, left lateral. **I, J.** AMNH 37359, dimorph indeterminate. **I**, Ventral; **J**, left lateral. **K–M.** AMNH 47368, dimorph indeterminate. **K**, Right lateral; **L**, ventral; **M**, left lateral. **N–P.** AMNH 47105, dimorph indeterminate. **N**, Right lateral; **O**, apertural; **P**, ventral. **Q–T.** *Discoscaphites minardi* Landman et al., 2004, AMNH 47369, microconch, same locality as A–P. **Q**, Right lateral; **R**, apertural; **S**, ventral; **T**, left lateral. **U–X, c–f.** *Discoscaphites* spp., same locality as A–P. **U–X.** AMNH 47371. **U**, Right lateral; **V**, apertural; **W**, ventral; **X**, left lateral. **c–f.** AMNH 47374. **c**, Right lateral; **d**, apertural; **e**, ventral; **f**, left lateral. **Y–Z, a, b.** *Discoscaphites gulosus* (Morton, 1834), AMNH 47106, same locality as A–P. **Y**, Right lateral; **Z**, apertural; **a**, ventral; **b**, left lateral. All figures are $\times 1$.

and part of the flanks are obscured by matrix on the right side on the adapical end of the body chamber. This damage may be due to a lethal injury. The ventral and right side of the apertural margin are broken off.

The phragmocone is relatively involute.

The umbilicus is difficult to measure because it is covered with matrix on the left side and is missing altogether on the right side; it is approximately 3.5 mm in diameter. The phragmocone is 23.5 mm in diameter; the ratio of umbilical diameter to phragmocone di-

TABLE 8
Measurements of *Discoscaphites iris* (Conrad, 1858)^a

		WUS	HUS	WUS/ HUS	WMS	HMS	WMS/ HMS	WAPT	HAPT	WAPT/ HAPT
MACROCONCH										
Robust form										
AMNH 51060	c	16.6	19.2	0.86	21.0 ^b	21.7 ^b	0.97 ^b	—	—	—
	ic	15.8	18.2	0.87	20.4 ^b	21.1 ^b	0.97 ^b	—	—	—
AMNH 47367	c	—	—	—	20.9 ^b	21.5 ^b	0.97 ^b	—	—	—
	ic	12.4	16.8	0.74	—	—	—	—	—	—
MAPS A2060a1	c	13.1	16.1	0.81	18.2	17.3	1.05	—	—	—
	ic	—	—	—	17.0 ^b	19.5 ^b	0.87 ^b	—	—	—
Slender form										
AMNH 51059	c	—	—	—	14.0	15.2	0.92	—	—	—
	ic	7.7	12.3	0.63	12.8	15.2	0.84	—	—	—
AMNH 47360	c	—	—	—	—	—	—	—	—	—
	ic	11.6	16.8	0.69	12.8	17.1	0.75	12.2	12.5	0.98
AMNH 47361	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	—	—	—	13.3	14.1	0.94
AMNH 47348	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	11.0	16.4	0.67	—	—	—
AMNH 47358	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	—	—	—	12.7	13.8	0.92
AMNH 47357	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	13.5	16.2	0.83	—	—	—
MICROCONCH										
Robust form										
MAPS A2060a4	c	—	—	—	15.0	13.3	1.13	—	—	—
	ic	10.5	12.0	0.88	14.3	13.3	1.08	—	—	—
AMNH 47363	c	11.0	14.0	0.78	17.0	15.0	1.13	—	—	—
	ic	9.4	13.4	0.70	14.2	15.0	0.95	—	—	—
MAPS A2060a3	c	—	—	—	12.2	14.0	0.87	—	—	—
	ic	10.2	14.2	0.72	12.2	13.9	0.86	—	—	—
AMNH 47308	c	—	—	—	14.2	13.1	1.08	—	—	—
	ic	—	—	—	11.8	13.1	0.90	—	—	—
MAPS A2060a2	c	10.4	12.8	0.81	14.9	13.4	1.11	—	—	—
	ic	—	—	—	14.1	13.4	1.05	—	—	—
AMNH 51055	c	9.4	12.4	0.76	12.1	13.3	0.91	—	—	—
	ic	9.1	12.4	0.74	11.1	13.3	0.83	—	—	—
Slender form										
AMNH 51057	c	—	—	—	9.5	10.0	0.95	—	—	—
	ic	—	—	—	8.0	10.7	0.75	—	—	—
AMNH 51058	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	11.2	11.8	0.95	—	—	—
AMNH 47105	c	—	—	—	—	—	—	—	—	—
	ic	5.9	9.4	0.63	—	—	—	—	—	—
AMNH 47356	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	11.3	12.2	0.93	—	—	—
AMNH 47342	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	—	—	—	9.4	11.1	0.85
AMNH 47345	c	—	—	—	—	—	—	—	—	—
	ic	—	—	—	—	—	—	11.1	11.3	0.98
AMNH 51056	c	—	—	—	10.8	12.8	0.84	—	—	—
	ic	9.4	12.5	0.75	—	—	—	—	—	—

^aWUS = whorl width at ultimate septum; HUS = whorl height at ultimate septum; WMS = whorl width at midshaft; HMS = whorl height at midshaft; WAPT = whorl width at aperture; HAPT = whorl height at aperture; c = costal section; ic = intercostal section.

^b Estimate; see figure 16 for an explanation of measurements.

ameter is 0.15; the ratio of umbilical diameter to shell diameter is 0.10. In side view, the venter of the phragmocone passes smoothly into the venter of the body chamber, describing a broad arc. There is no visible gap between the phragmocone and the body chamber. The apertural margin is slightly flexuous and the apertural angle is very low (27°). The umbilical seam of the body chamber is straight with a slight bulge. The body chamber is approximately 0.5 whorls long.

The whorl section of the phragmocone is compressed ovoid. The ratio of whorl width to height in intercostal section at the point of exposure and at the ultimate septum is 0.66 and 0.63, respectively. At the ultimate septum, the umbilical wall is steep and convex and the umbilical shoulder is sharply rounded. The flanks are very broadly rounded to flat with maximum width at one-quarter whorl height. They gently slope toward the venter but become more steeply inclined between the inner and outer ventrolateral tubercles. The ventrolateral margin is sharply rounded and the venter is flat with a slightly raised midline.

The whorl section of the most adapical part of the body chamber is similar to that of the phragmocone, but the body chamber becomes more swollen at midshaft. The ratio of whorl width to height at midshaft is 0.84 and 0.92 in intercostal and costal sections, respectively. The umbilical wall is steep and convex and the umbilical shoulder is fairly abruptly rounded. The inner flanks are broadly rounded and inclined outward, the midflanks are nearly flat and gently converge toward the venter, and the outermost flanks between the inner and outer ventrolateral tubercles are broadly rounded and more steeply inclined toward the venter. The ventrolateral margin is fairly sharply rounded and the venter is very broadly rounded. The body chamber tapers adorally with a reduction in whorl width and height. The whorl width and height at the point of recurvature are 11.5 mm and 12.8 mm, respectively; the ratio of whorl width to height is 0.90.

The ornament on the phragmocone is poorly preserved and consists of prorsiradiate ribs and inner and outer ventrolateral tubercles. Branching and intercalation occur at

two-thirds whorl height. Near the adoral end of the phragmocone, the ribs are bullate on the inner flanks at the site of the future umbilicolateral tubercles. Midflank tubercles are not present although this may be due to poor preservation. The inner ventrolateral tubercles, of which there are 16 on the exposed phragmocone, occur on every rib. They are evenly spaced at distances of 1.5 mm on the adapical end of the phragmocone, becoming more widely spaced toward the adoral end; the distance between the two most adoral tubercles is 3 mm. The outer ventrolateral tubercles are smaller than the inner ventrolateral tubercles but are more distinct, numerous, and more closely spaced. There are 27 of them on the exposed phragmocone. They are tiny and evenly spaced at distances of approximately 1 mm on the adapical end of the phragmocone, becoming abruptly larger and more widely spaced on the adoral one-third of the phragmocone. The distance between the two most adoral tubercles is approximately 2 mm. Some tubercles are matched and others are not on either side of the ventral margin. A few ribs are present on the venter on the adapical part of the phragmocone but most of the venter is smooth.

Ribs are not well defined on the posterior part of the body chamber but become more conspicuous on the adoral one-third. There are six strongly prorsiradiate, moderately widely spaced ribs on the hook, which become more closely spaced toward the aperture. The venter is smooth. There are four rows of tubercles. Three umbilicolateral tubercles are preserved on the left side at approximately one-quarter whorl height. They are evenly spaced at distances of 4.5 mm. The middle tubercle is the most prominent tubercle on the specimen. The midflank tubercles occur at midwhorl height and are smaller and more numerous than the umbilicolateral tubercles. The largest and most widely spaced midflank tubercles (5.5 mm apart) occur at midshaft; they diminish in size and spacing toward the aperture. The inner ventrolateral tubercles are slightly more prominent than the midflank tubercles. Eleven inner ventrolateral tubercles are preserved on the body chamber on the left side. They are fairly evenly spaced at distances of 5 mm on the shaft but become more closely spaced

toward the aperture. The outer ventrolateral tubercles are smaller and less distinct than the inner ventrolateral tubercles. There are 11 outer ventrolateral tubercles preserved on the body chamber on the left side, equal to the number of inner ventrolateral tubercles. They are fairly evenly spaced at distances of approximately 4 mm. Tubercles are slightly offset from one side of the venter to the other. The distance between tubercle rows at midshaft starting with the umbilicolateral row is 5.5 mm, 4 mm, and 2.5 mm. A composite suture is illustrated at a whorl height of 7.9 mm (fig. 41D). The first lateral saddle (E/L) and lobe (E) are both asymmetrically bifid.

AMNH 47360 consists of the adoral end of the phragmocone and body chamber, with the venter on the adoral part of the shaft missing and the right side of the specimen worn (fig. 35H–L). The impression of the left side of the specimen is preserved in matrix. The body chamber is slightly more than 0.5 whorls long. The umbilical shoulder is weakly swollen in side view. The whorl section at the base of the body chamber is compressed ovoid with a ratio of whorl width to height of 0.69. The body chamber is swollen at midshaft with a ratio of whorl width to height of 0.75 in intercostal section. The umbilical wall is steep and convex and the umbilical shoulder is fairly abruptly rounded. The inner flanks are broadly rounded and inclined outward, the midflanks are nearly flat and gently converge toward the venter, and the outer flanks are broadly rounded and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is very broadly rounded. The whorl section at the aperture is less compressed than that at midshaft with a ratio of whorl width to height of 0.98.

The ornament on the body chamber is better preserved on the left side. There are four rows of tubercles that occur on poorly defined ribs. Ribs swing backward on the inner flanks, forward on the midflanks, and back again on the outer flanks. Very fine ribs are visible on a peel made from the impression of the left side of the specimen. Intercalation and branching occur at the umbilicolateral tubercles or at the equivalent whorl height. Pairs of ribs loop between umbilicolateral and midflank tubercles at midshaft. There are

six umbilicolateral tubercles that extend to the aperture. They are unevenly spaced with the maximum distance between the two most adoral tubercles of approximately 6.5 mm. Nor are they of equal strength; the next to last tubercle is the most prominent tubercle on the specimen. A row of five tubercles occurs on the midflanks with a distance of approximately 9 mm between the two most adoral tubercles. There are eight slightly more prominent inner ventrolateral tubercles that are approximately evenly spaced at distances of 5–7 mm. The outer row of ventrolateral tubercles, which extends to the aperture, is incomplete due to postmortem breakage, but there would have originally been at least 10 tubercles, two more than the number of inner ventrolateral tubercles. The distance between the two most adoral tubercles is 5 mm. The distance between tubercle rows at midshaft starting with the umbilicolateral row is 5 mm, 4 mm, and 4 mm.

There are nine other macroconchs in cluster 1, of which we describe four, but all are more fragmentary than AMNH 47360 and AMNH 51059. AMNH 51061 is an internal mold of one-half of a compressed body chamber (fig. 35Q–T). Ribs are present in addition to the four rows of tubercles and are conspicuous on the right side. Ribs swing slightly backward on the umbilical shoulder and then forward on the inner one-half of the flanks. They become bullate at one-quarter whorl height, where they bifurcate and join the midflank tubercles. Straight to weakly convex ribs link the midflank to the inner ventrolateral tubercles on the adoral part of the shaft and hook. Ribs become increasingly prorsiradiate adorally and connect the inner and outer ventrolateral tubercles. There are two ribs on the venter near the apertural margin. They cross the venter with a slight adoral projection and join pairs of outer ventrolateral tubercles on the opposite side of the venter. The distance between tubercle rows at midshaft starting with the umbilicolateral row is 4.5 mm, 5 mm, and 3.5 mm.

AMNH 47361 is one-half of a body chamber with most of the right side worn away (fig. 35U–X). The apertural margin is slightly flexuous with a constriction. The whorl section at the aperture is subquadrate with a ratio of whorl width to height of 0.94. All

four rows of tubercles are present, with one of the umbilicolateral tubercles being the most prominent. The most complete row of tubercles is the inner ventrolateral row of which there are 11 tubercles on the body chamber including one on the apertural margin. The spacing between rows of tubercles at midshaft starting with the umbilicolateral row is 5.5 mm, 5.5 mm, and 4.5 mm.

AMNH 47357 is most of a robust body chamber minus the hook, although the adapical end is not well preserved (fig. 35M–P). The whorl section at midshaft is compressed ovoid with maximum width at one-quarter whorl height. The intercostal ratio of whorl width to whorl height is 0.83. The umbilical wall is steep and subvertical and the umbilical shoulder is fairly abruptly rounded. The inner flanks are broadly rounded, the midflanks are nearly flat and gently converge to the venter, and the outer flanks are broadly rounded and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is nearly flat. The body chamber is covered with swollen, poorly defined prorsiradiate ribs bearing four rows of tubercles. There are three umbilicolateral tubercles perched just outside the umbilical shoulder. The middle one of these tubercles points slightly backward and is the most prominent tubercle on the specimen. There are five midflank, six inner ventrolateral, and eight outer ventrolateral tubercles. The outer ventrolateral tubercles are paired on either side of the venter and are joined by weak swollen ribs.

AMNH 47355 is the middle portion of a flat sided body chamber minus part of the venter (fig. 36A–D). Ribs are rectiradiate and nearly straight on the adapical end of the specimen becoming prorsiradiate and weakly concave toward the adoral end. All four rows of tubercles are present on the left side. A groove occurs on the flanks on the right side at one-third whorl height and represents a repaired injury. As a result, the midflank row of tubercles is not present on this side but the ribs are better developed.

MICROCONCH DESCRIPTION

Most of the robust microconchs comprise cluster 2 (MAPS A2060a2, A2060a3,

AMNH 47308, 47363, and 51055). AMNH 47363 is an internal mold of a body chamber with most of the venter of the shaft worn away and part of the hook missing (fig. 38A–D). There is an impression of the phragmocone on the dorsum. The specimen retains some patches of iridescence, probably because a very thin layer of shell material is preserved. In side view, the umbilical shoulder forms a curve, which is the same as that of the venter. The apertural margin shows a constriction.

The body chamber grows rapidly in width in passing from the base to midshaft. Thereafter, the width remains nearly the same, but the height diminishes slightly to the point of recurvature. The ratio of whorl width to height in intercostal section is 0.70, 0.95, and 1.03 at the base of the body chamber, midshaft, and point of recurvature, respectively. The umbilical wall is nearly flat and subvertical at midshaft and the umbilical shoulder is fairly abruptly rounded. The flanks are broadly rounded and gently inclined toward the venter, becoming more steeply inclined at three-quarters whorl height.

The ornament on a peel of part of the phragmocone shows inner and outer ventrolateral tubercles linked by prorsiradiate ribs. The number of outer ventrolateral tubercles exceeds the number of inner ventrolateral tubercles. The outer ventrolateral tubercles are tiny and evenly spaced at distances of approximately 1.25 mm. The tubercles are paired on either side of the venter and linked by ribs showing a very slight adoral projection. There are approximately 8 ribs/cm on the venter based on an average distance of 1.25 mm between ribs.

The ornament on the body chamber consists of four rows of tubercles; some of these tubercles occur on swollen broad ribs. Two straight rectiradiate ribs occur on the adapical end of the body chamber on the left side. There are four umbilicolateral tubercles perched on the umbilical shoulder. They are evenly spaced at distances of 6 mm and extend to the aperture. The two middle ones are the most prominent tubercles on the specimen. There are seven midflank tubercles that are evenly spaced at distances of approximately 6 mm and eight inner venterolateral tubercles, although some of these are worn

away at midshaft. The row of outer ventrolateral tubercles is only preserved on the adapical portion of the specimen.

MAPS A2060a2 is most of a robust body chamber minus part of the hook with the impression of the inner whorls (fig. 38E–H). The whorl section at the base of the body chamber is compressed ovoid with maximum width at one-quarter whorl height in costal and intercostal section; the ratio of whorl width to whorl height is 0.81 in costal section. The umbilical wall is steep and convex and the umbilical shoulder is fairly abruptly rounded. The inner flanks are nearly flat and inclined slightly outward, the midflanks are nearly flat and gently converge toward the venter, and the outer flanks are broadly rounded and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is narrow and flat. The whorl width and height expand gradually into the body chamber. The whorl section at midshaft is subquadrate with maximum width at the umbilical shoulder in both costal and intercostal section. The ratio of whorl width to height in intercostal section is 1.05. The umbilical wall is broad, weakly convex to nearly flat, and inclined slightly outward; the umbilical shoulder is abruptly rounded. The flanks are broadly rounded and gently converge toward the venter, becoming more steeply convergent near the inner ventrolateral tubercles. The ventrolateral shoulder is fairly abruptly rounded and the venter is flat.

The ornament on a peel of part of the phragmocone shows rows of inner and outer ventrolateral tubercles. Straight prorsiradiate ribs join the inner and outer ventrolateral tubercles. The outer ventrolateral tubercles are tiny and are evenly spaced at distances of approximately 1.25 mm. There are approximately 1.5 times as many outer as inner ventrolateral tubercles. The outer ventrolateral tubercles are matched on either side of the venter on the adoral one-half of the peel and alternate on the adapical one-half. Ribs cross the venter with a very slight adoral projection and link paired or offset outer ventrolateral tubercles. There are approximately 8 ribs/cm based on an average distance of 1.25 mm between ribs.

On the body chamber, four rows of tuber-

cles are prominent and occur on fairly strong, swollen prorsiradiate ribs. Ribs bifurcate and swing forward from the umbilical tubercles connecting the midflank and inner ventrolateral tubercles. Ribs weaken or disappear between the inner and outer ventrolateral tubercles. The most prominent tubercles are the umbilical tubercles, followed by the inner ventrolateral tubercles, the midflank tubercles, and the outer ventrolateral tubercles. As counted on the right side, there are four umbilical tubercles spaced at distances of 4.5–6 mm, seven midflank tubercles spaced at distances of 3.5–5 mm, seven inner ventrolateral tubercles spaced at distances of 5–7 mm, and eight outer ventrolateral tubercles spaced at distances of 5.5 mm. The distance between tubercle rows at midshaft starting with the umbilical row is 4 mm, 4.5 mm, and 3.5 mm. The spacing between paired ventrolateral tubercles on either side of the venter ranges from 3 mm at the adapical end to 4.5 mm at the adoral end of the specimen.

MAPS A2060a4 is most of a robust body chamber and adoral part of a phragmocone attached to a siderite nodule (fig. 34I, J). The ventral and left side of the hook are missing. The whorl section is compressed ovoid at midshaft with an intercostal ratio of whorl width to height of 1.08. The maximum width is at the umbilical shoulder. The midflanks are broadly rounded and gently converge toward the venter, and the outer flanks are nearly flat and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is nearly flat.

Four rows of tubercles occur on swollen, poorly defined prorsiradiate ribs. The right side preserves the ornamentation better. There are three umbilical tubercles on the body chamber extending to the aperture. The middle tubercle is the most prominent tubercle on the specimen and exhibits a steep adapical and more gently sloping adoral side. There are seven midflank tubercles that occur just dorsal of midwhorl height. They are evenly spaced at distances of 4.5–5.5 mm except near the aperture where there is an increase (8 mm) and then a decrease (4.5 mm) in spacing. A row of 11 inner ventrolateral tubercles (one is presumed to have been present but is missing due to breakage) occurs

at two-thirds whorl height and extends to the aperture. The tubercles occur at approximately equal distances of 4.5–5.5 mm. Only part of the outer ventrolateral row of tubercles is preserved. There are eight outer ventrolateral tubercles versus five inner ventrolateral tubercles on the adapical one-half of the body chamber. The distance between tubercle rows at midshaft, starting with the umbilical row, is 4.25 mm, 4.5 mm, and 3.5 mm. The distance between outer ventrolateral tubercles on either side of the venter is 4.75 mm.

The microconchs in cluster 1 represent more compressed forms. The best preserved microconch in cluster 1 is AMNH 51057, an internal mold of a body chamber with the remnant of the inner whorls (fig. 37A–D). It is 30.2 mm in maximum diameter. Adhering matrix on the left side obscures the umbilical margin but on the right side, the umbilical margin is tightly curved in side view. The body chamber is compressed and gradually expands in height and width to the aperture, which shows a constriction. The ratio of whorl width to height at midshaft is 0.75 in intercostal section. The umbilical wall is flat and inclined outward and the umbilical shoulder is sharply rounded. The flanks are nearly flat and subparallel, becoming more steeply inclined toward the venter at three-quarters whorl height. The ventrolateral shoulder is sharply rounded and the venter is flat.

The ornament on the body chamber consists of four rows of tubercles, some of which occur on weak, broad, straight to arcuate ribs. The only well-defined rib is just adapical of the apertural margin. Five umbilicolateral tubercles are perched on the umbilical shoulder and extend to the aperture. The four most adoral tubercles are evenly spaced at distances of approximately 4 mm. The midflank tubercles begin as bullate swellings, becoming more tuberculate at midshaft, and extend to the aperture. There are 12 inner ventrolateral tubercles that become more closely spaced adorally. The spacing between the two most widely spaced tubercles is 5 mm and the spacing between the two most closely spaced tubercles is 3 mm. There are 19 outer ventrolateral tubercles, that is, 1.6 times the number of inner ventrolateral tu-

bercles. They are most widely spaced (4.5 mm) at midshaft and most closely spaced (2 mm) near the base of the body chamber. The ventrolateral tubercles are generally offset from one side of the venter to the other. The distance at midshaft between the four rows of tubercles, starting with the umbilicolateral row, is 3.5 mm, 3.5 mm, and 2.5 mm.

There are eight other microconchs in cluster 1, all of them relatively compressed. We describe three. AMNH 51058 is an internal mold of the adoral one-half of a body chamber (fig. 37I–L). The right side is partly covered with matrix, possibly obscuring a hole in the shell. The whorl section at midshaft is nearly subquadrate with a ratio of whorl width to height of 0.95 in intercostal section. All four rows of tubercles are well developed with the umbilical tubercles being the largest, least numerous, and most widely spaced and the outer ventrolateral tubercles being the smallest, most numerous, and most closely spaced.

AMNH 47356 is the middle portion and part of the hook of a body chamber (fig. 37Q–T). The whorl section at midshaft is compressed ovoid with maximum width at the umbilical shoulder in costal section and at one-third whorl height in intercostal section. The intercostal ratio of whorl width to whorl height is 0.93. The tubercles occur on poorly defined, swollen prorsiradiate ribs. The strongest tubercles are the umbilical tubercles followed by the inner ventrolateral tubercles. The distance between tubercle rows at midshaft, starting with the umbilical row, are 4 mm, 5.5 mm, and 3 mm. The distance between outer ventrolateral tubercles on either side of the venter at midshaft is 4 mm.

AMNH 47353 is part of the body chamber of a fairly compressed specimen (fig. 37c–f). The ornament consists of fairly strong prorsiradiate ribs with four rows of tubercles. However, the spacing of the tubercle rows differs from that in most other specimens. The umbilical row is perched on the umbilical shoulder, but the midflank and “inner ventrolateral row” occur just above and below midwhorl height, respectively. The “inner” and outer ventrolateral rows are spaced widely apart. The distance between rows on the middle of the specimen starting with the

umbilical row is 3 mm, 3.5 mm, and 5 mm. The distance between ventrolateral tubercles on either side of the venter is 3 mm.

AMNH 47105 from AMNH loc. 3345 (but not from cluster 1) is most of a body chamber minus the hook and venter (fig. 39A–D). There is some iridescent shell on the umbilical wall on the right side. The base of the body chamber is well preserved. It is compressed ovoid with a ratio of whorl width to height of 0.63 in intercostal section. The umbilical wall is steep and convex and the umbilical shoulder is sharply rounded. The flanks are flat and nearly subparallel. The ventrolateral shoulder is fairly abruptly rounded and the venter is nearly flat.

There are six umbilical tubercles perched on the umbilical shoulder. They are arcuate and evenly spaced at distances of approximately 2.5 mm. Ribs arise in pairs from these tubercles and are prorsiradiate on the flanks. The more adoral rib of each pair is weaker and convex and the more adapical rib is stronger and concave to straight, and links to a midflank tubercle. Weaker, finer ribs intercalate between the umbilical tubercles. The midflank tubercles are bullate and less prominent than the umbilical tubercles and are spaced at distances of 3.5–4 mm. Due to the erosion of the venter, some of the inner ventrolateral tubercles and all of the outer ventrolateral tubercles are missing.

AMNH 51056 is the adapical one-half of a body chamber (fig. 39E–H). It is from AMNH loc. 3345 (but not cluster 1) and resembles AMNH 47337 (fig. 37i–l) in having nearly flat flanks. The whorl section at midshaft is compressed subquadrate with a ratio of whorl width to height of 0.84. The umbilical tubercles are arcuate with steep adapical sides and more gently inclined adoral sides. Swollen, arcuate ribs link the midflank tubercles to the inner ventrolateral tubercles, which, after the umbilical tubercles, are the second most prominent tubercles on the specimen. These tubercles also exhibit steep adapical sides and more gently sloping adoral sides. The outer ventrolateral tubercles are less prominent than the inner ventrolateral tubercles. The distance between tubercle rows at midshaft, starting with the umbilical row, is 4.25 mm, 4 mm, and 2.5 mm. The outer ventrolateral tubercles are very closely

spaced on either side of the venter, approximately 3 mm apart. Based on the regular spacing of tubercles on most of the specimens, a single outer ventrolateral tubercle, one in each row on either side of the venter, seems to have been skipped during growth. A shallow groove appears on the midventer at this point suggesting a repaired injury.

DIMORPH INDETERMINATE

There are many specimens, most from cluster 1, that are too fragmentary to determine the dimorph. We describe two of the more complete specimens.

AMNH 47349 is the shaft of a fairly compressed, although slightly crushed body chamber, probably of a macroconch (Fig. 36S–V). The flanks are nearly flat and gently converge toward the venter, as in AMNH 47337 and 51056. The ribs are weak, prorsiradiate, and slightly flexuous. All four rows of tubercles are present with the outer and inner ventrolateral rows being very closely spaced to one another. The distances between rows at midshaft, starting with the umbilicolateral row, are 3.5 mm, 4 mm, and 2.25 mm. The distance between ventrolateral tubercles on either side of the venter is also small, approximately 3 mm.

AMNH 47368 is the adoral half of the body chamber of a fairly robust specimen, probably a macroconch (fig. 39K–M). It is from AMNH loc. 3345 but not from cluster 1. The right side is worn away. A small piece of the phragmocone is still attached. This piece and part of the body chamber retain some shelly iridescence. The ornament consists of four rows of tubercles but the spacing between them differs from that in most other specimens. Two umbilical tubercles occur on the umbilical shoulder, the adapical one of which is the most prominent tubercle on the specimen. Two tubercles occur on the innermost flanks near the aperture. A more prominent row of tubercles occurs slightly ventral of midwhorl height. These are linked by short arcuate ribs to a row of ventrolateral tubercles. The distance between tubercle rows near the aperture, starting with the umbilical row and excluding the row of only two tubercles, is 3 mm, 3 mm, and 4 mm.

DISCUSSION: *Discoscaphites iris* is charac-

terized by four rows of tubercles borne on weak to coarse ribs. In macroconchs, the distance between the umbilical and midflank tubercles is equal to or *slightly greater than* that between the midflank and inner ventrolateral tubercles, which is greater than the distance between the inner and outer ventrolateral tubercles. Because the whorl height in microconchs is smaller than that in macroconchs, the spacing of tubercles is slightly different. The distance between the umbilical and midflank tubercles is approximately equal to or *slightly less than* that between the midflank and inner ventrolateral tubercles, which is greater than the distance between the inner and outer ventrolateral tubercles. The number of outer ventrolateral tubercles on the body chambers of macroconchs is approximately 1–1.5 times the number of inner ventrolateral tubercles. The most prominent tubercles are the umbilicolateral tubercles, followed by the inner ventrolateral tubercles. The midflank and outer ventrolateral tubercles are equally small.

Discoscaphites iris was originally described from the Owl Creek Formation, Tiptah County, Mississippi, by Conrad (1858: 335, pl. 35, fig. 23). Kennedy and Cobban (2000) described and illustrated many additional specimens from this locality, reflecting a range of variation from slender to robust forms. The strength of the tubercles covaries with the degree of inflation. The holotype is a robust specimen, and several other specimens, presumably part of Conrad's original material, now housed in the Academy of Natural Sciences of Philadelphia, represent both slender and robust forms.

As in other scaphites, it is tempting to distinguish the end members of this kind of morphological series and assign them different species names. However, there are many intermediaries and choosing the dividing line is difficult and arbitrary. As a result, we prefer to regard all of our specimens as conspecific.

Kennedy and Cobban (2000: 185, fig. 6, pl. 1, figs. 1–11) described *Discoscaphites sphaeroidalis* Kennedy and Cobban, 2000, from the Owl Creek Formation in northeastern Mississippi. According to them, this species is close to *D. iris* but differs from it in having a more inflated shape and more

strongly ribbed phragmocone. Many of the coarsely ornamented specimens in our collection resemble the holotype of *D. sphaeroidalis*, but none of them retains enough of the phragmocone to detect the presence of unusually strong ribbing diagnostic of this species. Therefore, we refer all the robust specimens in our collection to *D. iris*.

Discoscaphites iris differs from *Discoscaphites conradi* (Morton, 1834) and *Discoscaphites gulosus* (Morton, 1834) in having four rows of tubercles. In addition, the outer ventrolateral tubercles are more widely spaced in *Discoscaphites iris* than in *Discoscaphites conradi*. *Discoscaphites iris* differs from *Discoscaphites minardi* Landman et al., 2004, chiefly in that the midflank tubercles are sharp and well developed in *D. iris* whereas they are weak and bullate, if they exist at all, in *D. minardi*.

OCCURRENCE: Upper part of the New Egypt Formation and as reworked material at the base of the Hornerstown Formation, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey. Elsewhere in New Jersey, this species occurs in the upper part of the New Egypt Formation in the Crosswicks Creek Drainage, southwestern Monmouth County (Landman et al., in prep. b), and at the top of the Tinton Formation and as reworked material at the base of the Hornerstown Formation, Manasquan River Drainage, central Monmouth County (Landman et al., in prep. a). *Discoscaphites iris* is also known from the upper part of the Severn Formation, Kent and Anne Arundel Counties, Maryland (Landman et al., 2004). On the Gulf Coastal Plain, it occurs in the Owl Creek Formation and as reworked material at the base of the Clayton Formation in Mississippi, Tennessee, and Missouri (Stephenson, 1955; Sohl, 1960, 1964; Kennedy and Cobban, 2000). It is the name bearer of the *Discoscaphites iris* Zone on the Gulf and Atlantic Coastal Plains, which represents the upper part of the upper Maastrichtian, corresponding to the upper part of calcareous nannofossil Subzone CC26b.

Discoscaphites minardi Landman et al.,
2004

Figures 39Q–T, 40A–D, J–P

TYPE: The holotype is AMNH 47288, a macroconch, from AMNH loc. 3252 from

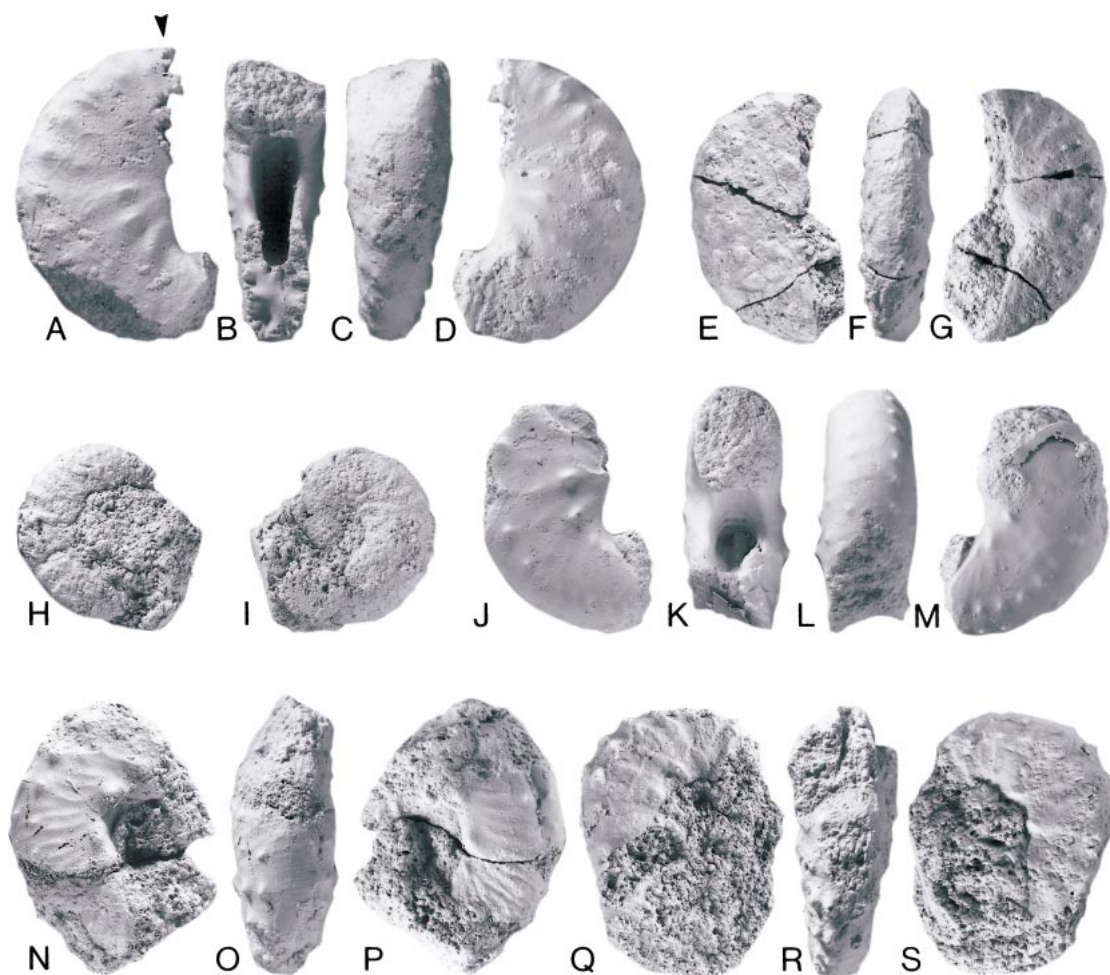


Fig. 40. **A–D, J–P.** *Discoscaphites minardi* Landman et al., 2004. **A–D.** MAPS A2059b2, macroconch, upper New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, AMNH loc. 3347, northwest of Eatontown, Monmouth County, New Jersey. **A**, Left lateral; **B**, apertural; **C**, ventral; **D**, left lateral. **J–M.** AMNH 47307, macroconch, upper New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, AMNH loc. 3346, northwest of Eatontown, Monmouth County, New Jersey. **J**, Right lateral; **K**, apertural; **L**, ventral; **M**, left lateral. **N–P.** AMNH 47305, microconch, same locality as J–M. **N**, Right lateral; **O**, ventral, **P**, left lateral. **E–I, Q–S.** *Discoscaphites* spp., same locality as J–P. **E–G.** AMNH 47301. **E**, Right lateral; **F**, ventral; **G**, left lateral. **H, I.** AMNH 47300. **H**, Right lateral; **I**, left lateral. **Q–S.** AMNH 47304. **Q**, Right lateral; **R**, ventral; **S**, left lateral. All specimens are $\times 1$.

the top of the Severn Formation, Betterton quadrangle, Kent County, Maryland.

MATERIAL: There are four specimens: two macroconchs (MAPS A2059b2 and AMNH 47307) and one microconch (AMNH 47305) from AMNH locs. 3346 and 3347, from the upper part of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation, near Eatontown, Monmouth County,

New Jersey, and one microconch (AMNH 47369) from AMNH loc. 3345 from the New Egypt/Hornerstown formational contact, near Eatontown, Monmouth County, New Jersey.

MACROCONCH DESCRIPTION

AMNH 47307 is the adoral one-half of a body chamber with part of the venter and

aperture missing (fig. 40J–M). The flanks are nearly flat and subparallel and the venter is broadly rounded. The whorl section at the aperture is subquadrate with a ratio of whorl width to height of 0.87. The dorsal projection of the aperture is preserved. The ornament is subdued with faint, straight, widely spaced prorsiradiate ribs that become more closely spaced near the apertural margin. Rows of umbilicolateral and inner and outer ventrolateral tubercles are present as well as a row of weak midflank swellings. The umbilicolateral tubercles are spaced at distances of 5 mm at midshaft. Ten radial swellings are visible on the midflanks on the left side of the fragment and extend to the aperture. The distance between midflank swellings at midshaft is 3 mm. There are an equal number of inner and outer ventrolateral tubercles on the hook—seven in each row, as counted on the left side; both rows extend to the aperture. The distance between tubercle rows at midshaft, starting with the umbilicolateral row and including the midflank row, is 4 mm, 5 mm, and 4.5 mm.

MAPS A2059b2 from AMNH loc. 3347 is most of a body chamber minus the ventral one-half of the hook (fig. 40A–D). The umbilical shoulder shows a bulge in side view. There is the impression of the phragmocone. The base of the body chamber is well preserved and is compressed ovoid with a ratio of whorl width to height of 0.55. The umbilical wall is steep and convex and the umbilical shoulder is fairly abruptly rounded. The inner flanks are flat and slightly divergent, the midflanks are nearly flat and subparallel, and the outer flanks are very broadly rounded and gently converge to the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is broadly rounded. The whorl width expands more rapidly than the whorl height and the ratio of whorl width to height at midshaft is 0.68.

Ribs are straight on the inner flanks at midshaft. They change from rursiradiate to prorsiradiate adorally and terminate in concave umbilicolateral bullae. Ribs swing forward in a straight line on the midflanks connecting umbilicolateral bullae to inner ventrolateral tubercles. On the left side, one rib bears two additional bullae, one bulla just dorsal and another just ventral of midflank,

and another rib bears a single, weak bulla just dorsal of midflank. The inner ventrolateral tubercles are relatively prominent, given the compressed shape of the shell. On the adapical one-half of the specimen on the right side, these tubercles occur on swollen, concave ribs. The tubercles are evenly spaced at distances of 4.5–5.5 mm at midshaft. They are linked by prorsiradiate swellings to an equal number of outer ventrolateral tubercles, which are also spaced at distances of approximately 5 mm at midshaft; the outer ventrolateral tubercles alternate on either side of the venter. The distance between tubercle rows at midshaft, starting with the umbilicolateral row and including the midflank row, is 3.5 mm, 7.5 mm, and 3.5 mm. The distance between tubercles on either side of the venter is 5 mm.

MICROCONCH DESCRIPTION

AMNH 47305 is the adoral one-half of a body chamber (fig. 40N–P). It is 35.6 mm in maximum length. It is slightly crushed and there is a break through the hook. The whorl section just adoral of midshaft is compressed ovoid with maximum width at the umbilical shoulder in costal and intercostal section. The umbilical wall is flat and inclined outward and the umbilical shoulder is fairly abruptly rounded. The inner and midflanks are very broadly rounded and gently converge toward the venter and the outer flanks (between the inner and outer ventrolateral tubercles) are broadly rounded and converge more steeply toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is broadly rounded.

This specimen is distinguished by the presence of strong ribs on the entire piece of body chamber and the absence of a midflank row of tubercles. Four umbilical tubercles are perched on the umbilical shoulder on the right side and are the most prominent tubercles on the specimen. The distance between umbilical tubercles slightly adoral of midshaft is 6.5 mm. Broad, low ribs arise at or between the tubercles and are prorsiradiate and slightly convex on the flanks. They become more closely spaced, straighter, and more prorsiradiate toward the aperture. The distance between ribs slightly adoral of mid-

shaft is approximately 1 mm. Pairs of ribs loop to the inner ventrolateral tubercles, and at least one rib intercalates at midwhorl height and extends to an outer ventrolateral tubercle. The inner ventrolateral tubercles are less prominent than the umbilical tubercles and are spaced at distances of approximately 4.5 mm slightly adoral of midshaft; because of poor preservation, it is unclear if these tubercles extend to the aperture. The outer ventrolateral tubercles are approximately the same size as the inner ventrolateral tubercles and are spaced at distances of approximately 6 mm slightly adoral of midshaft. The distance between the two rows of tubercles is 3.5 mm. The ventrolateral tubercles are matched on either side of the ventral margin with the distance between them being 8 mm slightly adoral of midshaft. Faint ribs cross the venter with a slight adoral projection.

AMNH 47369 is most of a body chamber of a compressed specimen (fig. 39Q–T). The ratio of whorl width to height at the aperture is 0.95. The flanks are nearly flat and covered with fairly straight prorsiradiate ribs, especially on the hook. The ribs become more closely spaced toward the aperture with intercalation at midwhorl height. Ribs cross the venter with a slight forward projection. The umbilical tubercles are well developed but the midflank tubercles are only represented by bullae. The inner ventrolateral tubercles are of equal size and spacing on the shaft, but abruptly diminish in size and spacing on the hook. The outer ventrolateral tubercles on the shaft are close to the inner ventrolateral tubercles, so that adjacent tubercles are connected by an elongate swelling. The outer ventrolateral tubercles disappear on the hook although this may be due to poor preservation.

DISCUSSION: Among these four specimens, AMNH 47307 (fig. 40J–M) perfectly matches the description of *Discoscaphites minardi*. In contrast, AMNH 47305 (fig. 40N–P) differs from *D. minardi* notably in the presence of fairly strong ribs. We provisionally include this specimen in *D. minardi*.

Discoscaphites minardi closely resembles *D. iris*, the main differences being that the flanks of the body chamber of *D. minardi* are flatter and less broadly rounded than those of *D. iris*, and that the midflank swellings are

weak and bullate in *D. minardi*, if they exist at all, whereas they are sharp and well developed in *D. iris*.

OCCURRENCE: Upper part of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation, and the uppermost 20 cm of the New Egypt Formation and base of the Hornerstown Formation, near Eatontown, northeastern Monmouth County, New Jersey. This species was originally described from the top of the Severn Formation, Betterton quadrangle, Kent County, Maryland (Landman et al., 2004).

Discoscaphites gulosus (Morton, 1834)

Figures 39Y–Z, a, b, 41E

Ammonites conradi var. *petechialis* Morton, 1834: 39, 40, pl. 16, fig. 1.

Ammonites conradi var. *gulosus* Morton, 1834: 39, pl. 16, fig. 2.

Ammonites conradi var. *navicularis* Morton, 1834: 40, pl. 19, fig. 4.

Discoscaphites gulosus (Morton, 1834). Landman and Waage, 1993: 212, figs. 156, 157, 159, 160, 167–180 (with full synonymy).

Discoscaphites gulosus (Morton, 1834). Cobban and Kennedy, 1995: 29, figs. 10.4, 10.5, 19.20–19.24, 20.8–20.12, 20.14–20.17, 21.18–21.21.

Discoscaphites gulosus (Morton, 1834). Kennedy et al., 1997: 21, figs. 20k–o, 21d, e.

TYPE: The holotype is ANSP 51552 from the Prairie Bluff Chalk at Prairie Bluff, Alabama.

MATERIAL: AMNH 47106, an internal mold of part of a phragmocone from the Main Fossiliferous Layer at the New Egypt/Hornerstown formational contact at AMNH loc. 3345 at Parkers Creek, near Eatontown, Monmouth County, New Jersey.

DESCRIPTION: AMNH 47106 is one-half of a phragmocone with part of the venter and flanks missing on the adapical end (fig. 39Y–Z, a, b). The specimen is 30.4 mm in diameter. The whorl section at the adoral end is compressed ovoid with maximum width at one-quarter whorl height. The ratio of whorl width to height is 0.72. The umbilical wall is convex and the umbilical shoulder is fairly sharply rounded. The inner flanks are well rounded and the outer flanks are broadly rounded and converge toward the venter. The ventrolateral shoulder is fairly abruptly rounded and the venter is nearly flat.

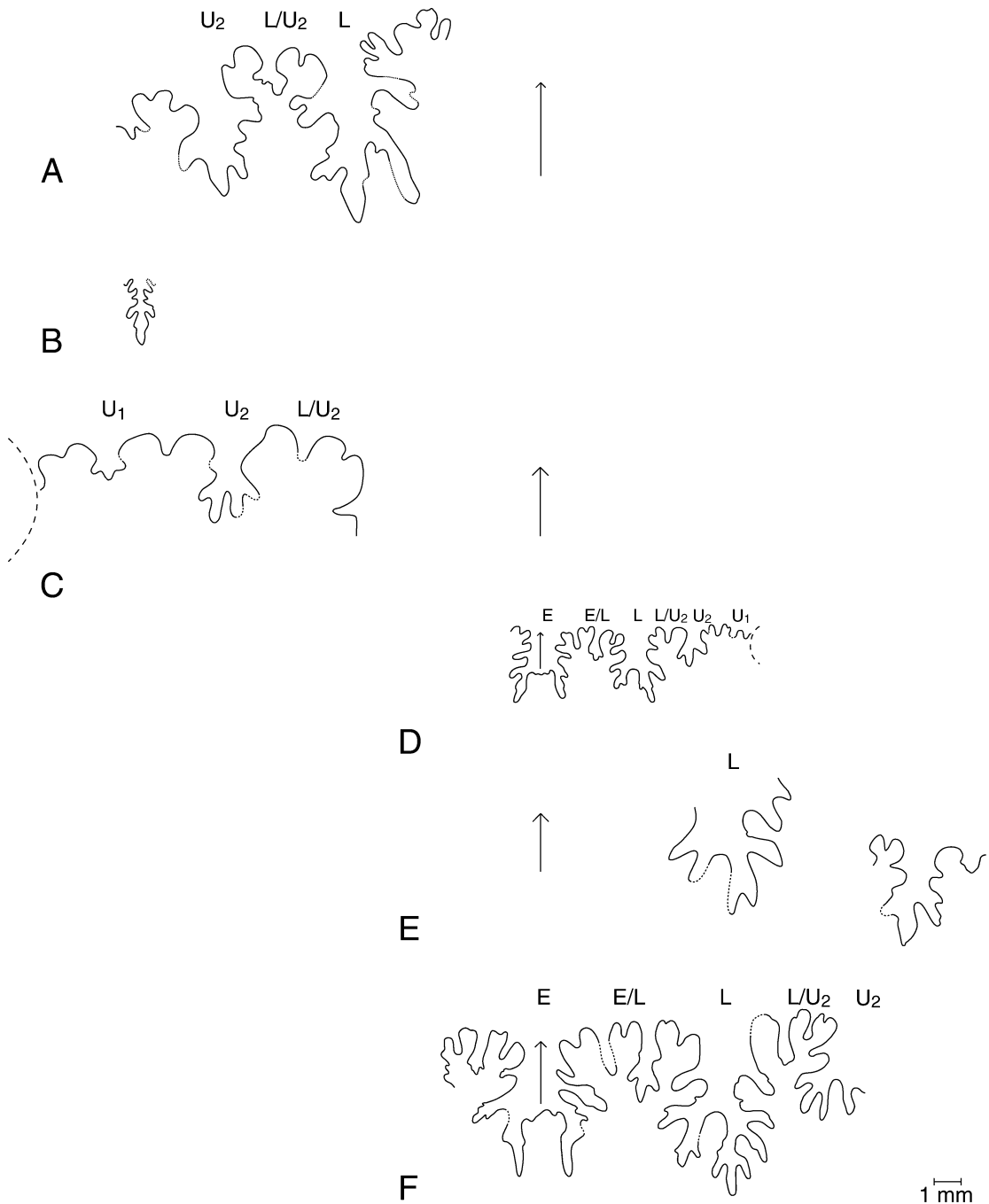


Fig. 41. **A–D.** *Discoscaphites iris* (Conrad, 1858), uppermost New Egypt Formation and basal Hornerstown Formation, AMNH loc. 3345, northwest of Eatontown, Monmouth County, New Jersey. **A, B.** AMNH 47365, a fragment of a macroconch, part of the last suture at a whorl height of approximately 18.2 mm and internal lobe of another suture on the inner whorls. **C.** AMNH 51060, a macroconch, part of the last suture at a whorl height of 19.7 mm. **D.** AMNH 51059, a macroconch, part of a composite of two sutures at a whorl height of 7.9 mm. **E.** *Discoscaphites gulosus* (Morton, 1834), AMNH 47106, same locality as A–D, part of a composite of two sutures at whorl heights of 17.3 mm and 17.6 mm. **F.** *Discoscaphites* sp., AMNH 47107, a fragment, same locality as A–D, part of a suture at a whorl height of approximately 10.3 mm.

The ornament consists of five rows of tubercles that occur on swollen prorsiradiate ribs. Intercalation and branching occur at one-third whorl height. The umbilical tubercles occur just outside the umbilical shoulder. The two most adoral tubercles are 5 mm apart. The two rows of inner and outer flank tubercles are not as prominent as the umbilical tubercles. They are evenly spaced and occur on every rib. These rows are more closely spaced to each other than the inner flank row is to the umbilical row (2.5 mm versus 4 mm as measured on a single rib on the right side 45° from the adoral end). The inner ventrolateral tubercles are as prominent as the umbilical tubercles and more prominent than the flank tubercles and are spaced at distances of 2.5 mm on the adapical part, becoming more widely spaced (5 mm) on the adoral part, as measured on the left side. The distance between the inner ventrolateral row and the outer flank row (3 mm as measured on the same rib as previously described) is slightly larger than that between the two flank rows. The outer ventrolateral tubercles are close to the inner ventrolateral tubercles, approximately 2.5 mm apart on the same rib as previously described. The outer ventrolateral tubercles are slightly smaller than the inner ventrolateral ones. The two most adoral outer ventrolateral tubercles are 3.5 mm apart. The outer ventrolateral tubercles are slightly offset from one side of the venter to the other. The suture shows part of a narrow first lateral lobe (L) and U_2 (fig. 41E). It is simplified but this is due perhaps to poor preservation.

DISCUSSION: This specimen, although fragmentary, matches in its shape and ornament other specimens of *Discoscaphites gulosus* illustrated by Jeletzky and Waage (1978) and Landman and Waage (1993). It is notable that there is no midventral row of tubercles on this specimen, which is characteristic of *D. gulosus* from the Prairie Bluff Chalk (e.g., Jeletzky and Waage, 1978, pl. 3, figs. 13, 14), although, in fact, this feature may be restricted to the body chamber.

OCCURRENCE: Top of the New Egypt Formation and base of the Hornerstown Formation, AMNH loc. 3345, Parkers Creek, near Eatontown, Monmouth County, New Jersey. A single specimen has also been re-

ported from the Navesink Formation (New Egypt Formation according to our usage) at the Inversand Pit, Gloucester County, New Jersey (Kennedy et al., 2000). On the basis of its preservation, it was probably derived from the lower part of the New Egypt Formation (W.B. Gallagher, personal commun., 2003). *Discoscaphites gulosus* occurs in several localities on the Gulf and Atlantic Coastal Plains including the Severn Formation, Prince Georges County, Maryland (Kennedy et al., 1997); the Peedee Formation, Brunswick County, North Carolina (Landman et al., 2004); and the Prairie Bluff Chalk, Alabama (Cobban and Kennedy, 1995). In the Western Interior, *D. gulosus* occurs in both the *Hoploscaphites nicolletii* and *Jeletzkytes nebrascensis* Zones of the Fox Hills Formation, South Dakota (Landman and Waage, 1993). However, it is more abundant in the lower of these two zones.

Discoscaphites spp.

Figures 36I, J, R, a–k, q–v, 37m, n, 39U–X, c–f, 40E–I, Q–S, 41F

MATERIAL: Approximately two dozen specimens, the majority of which are from the upper part of the New Egypt Formation and base of the Hornerstown Formation, AMNH loc. 3345, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey. The other locality is AMNH loc. 3346, the upper part of the New Egypt Formation, 1.5–2 m below the base of the Hornerstown Formation, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey. Of the specimens described, AMNH 47340, 47371, 47391, and 51063 are from AMNH loc. 3345 and AMNH 47304 is from AMNH loc. 3346.

DESCRIPTION: This material is all fragmentary. Some specimens show enough morphological features to differentiate them from known species of discoscaphites but there are not enough of these specimens to justify describing a new species. The vast majority of this material is, however, simply too worn or fragmentary for species identification. We describe five of the more complete specimens.

AMNH 47371 is the adoral part of the phragmocone and adapical part of the body

chamber of a compressed microconch (fig. 39U–X). A piece of the inner whorls of the phragmocone is also preserved. The flanks are covered by straight to slightly convex prorsiradiate ribs that bend forward to link the inner and outer ventrolateral tubercles. The umbilical tubercles are arcuate with steep adapical and more gently inclined adoral sides. The midflank tubercles are represented by weak bullae, which may have developed into tubercles on the adoral part of the body chamber.

AMNH 47340 is the adapical portion of a compressed body chamber with an extremely narrow venter (fig. 36t–v). There is a strong, arcuate prorsiradiate rib on the adoral end of the specimen. The umbilical and ventrolateral tubercles are present but the midflank tubercles are absent, although part of the shell in this area is covered by matrix. The two rows of ventrolateral tubercles are very closely spaced together, approximately 2.5 mm apart. The distance between ventrolateral tubercles on either side of the venter is also very small, approximately 2.5 mm.

AMNH 47391 is a piece of the middle of the shaft of a fairly compressed body chamber with nearly flat flanks (fig. 36k). Most of the right side is still attached to a phosphatic nodule, which bears the impressions of two other scaphites. The midflank and ventrolateral rows of tubercles are present but the umbilical row is absent, probably because too little of the specimen is preserved in this area. Several fine prorsiradiate ribs appear on the adoral end of the fragment. They swing backward on the umbilical shoulder and then forward on the inner flanks and cross the midflanks and outer flanks with a broad convexity.

AMNH 51063 is still attached to an indurated cluster of specimens that contains parts of three other specimens and impressions of three more (fig. 36R). It is an internal mold of the adapical one-half of a body chamber. The whorl section is compressed with nearly flat flanks and a flat, narrow venter. Two rows of ventrolateral tubercles are present, but the midflank and umbilical rows are not well developed, perhaps due to poor preservation. The distance between rows of inner and outer ventrolateral tubercles and between outer ventrolateral tubercles on ei-

ther side of the venter on the adoral end of the specimen is 2.5 mm in both instances.

AMNH 47304 is the adapical two-thirds of a body chamber (fig. 40Q–S). It is slightly distorted with adhering matrix on the dorsal side. Although crushed, the whorl section at midshaft was originally compressed with flat, nearly subparallel flanks and a very narrow venter. The specimen is distinguished by its broad prorsiradiate ribs, each of which bears an umbilicolateral tubercle or bulla. Ribs bifurcate and join the inner ventrolateral tubercles. Midflank tubercles are absent. The inner and outer rows of ventrolateral tubercles are very closely spaced together (2.5 mm apart at midshaft), so that adjacent tubercles occupy the same base. The distance between outer ventrolateral tubercles on either side of the venter is also small, approximately 4 mm. Tubercles are offset on either side of the venter on the adapical part of the specimen and paired on the adoral part.

OCCURRENCE: Upper part of the New Egypt Formation 1.5–2 m below the base of the Hornerstown Formation at AMNH loc. 3346 and in the uppermost 20 cm of the New Egypt Formation and base of the Hornerstown Formation at AMNH loc. 3345, Parkers Creek, near Eatontown, northeastern Monmouth County, New Jersey.

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APPENDIX 1
Marine Sections Spanning the K/T Boundary

No. ^a	Location	Lithostratigraphy	Biostratigraphy	Source
1	Parkers Creek, Monmouth Co., NJ	Hornerstown Fm./ New Egypt Fm.	Danian (Zone PO)/upper Maastrichtian (<i>D. iris</i> Zone)	this report
2	Crosswicks Creek, Monmouth Co., NJ	Hornerstown Fm./ New Egypt Fm.	Danian/upper Maastrichtian (<i>D. iris</i> Zone)	Landman et al., in prep. b
3	Manasquan River Drain- age, Monmouth Co., NJ	Hornerstown Fm./ Tinton Fm.	Danian/upper Maastrichtian (<i>D. iris</i> Zone)	Landman et al., in prep. a
4	Inversand Pit, Gloucester Co., NJ	Hornerstown Fm./ New Egypt Fm.	Danian/upper Maastrichtian (<i>D. iris</i> Zone)	Gallagher, 1993
5	Bass River Core, Burlington Co., NJ	Hornerstown Fm./ New Egypt Fm.	Danian (Zone PO)/upper Maastrichtian (<i>A. mayaroensis</i> Zone)	Olsson et al., 1997, 2002
6	Round Bay, Anne Arundel Co., MD	Brightseat Fm./ Severn Fm.	lower Paleocene/upper Maastrichtian (<i>D. iris</i> Zone)	Benson, 1976; Minard, 1980; Landman et al., 2004
7	Valhalla Core, Chowan Co., NC ^b	Beaufort Fm./ Cane Acre Fm.	lower Paleocene/ lower Campanian	J. Self-Trail, personal commun., 2004
8	Cape Hatteras Lighthouse Core 1, Dare Co., NC ^b	unnamed unit/ Shepherd Grove Fm.	lower Eocene/ upper Santonian– lower Campanian	J. Self-Trail, personal commun., 2004
9	Kure Beach Core, New Hanover Co., NC	Beaufort Fm./ Peedee Fm.	lower Paleocene/upper Maastrichtian (Zone CC26a)	J. Self-Trail, personal commun., 2004
10	Brunswick Co., NC	Castle Hayne Ls./ Peedee Fm.	middle–upper (?) Eocene/ upper middle Maastrichtian	Harris et al., 1986
11	Santee Coastal Reserve Core, Charleston Co., SC	Rhems Fm./ Peedee Fm.	Danian (Zone NP1)/upper Maastrichtian (Zone CC26b)	Edwards et al., 1999
12	Cannon Park Core, Charleston Co., SC	Rhems Fm./ Peedee Fm.	Danian (Zone NP1)/upper Maastrichtian (Zone CC26b)	Bybell et al., 1998
13	Orangeburg Core, ORG 393, Orange- burg Co., SC	Browns Ferry Fm./ Sawdust Landing Fm.	?/upper Maastrichtian	J. Self-Trail, personal commun., 2004
14	Savannah River Site, southwestern SC ^c	Ellentown Fm./ Peedee Fm.	Danian/Maastrichtian	Hargrove and Engelhardt, 1997
15	Albany Core, Dougherty Co., GA	Clayton Fm./ Providence Fm.	Danian/upper Maastrichtian	Firth, 1987, 1993
16	Ft. Gaines Core, Clay Co., GA	Clayton Fm./ Providence Fm.	Danian/upper Maastrichtian	Firth, 1993
17	eastern Alabama	Clayton Fm./ Providence Sand	Danian/upper Maastrichtian	Reinhardt, 1981
18	Millers Ferry, Wilcox Co., AL	Clayton Fm./ Prairie Bluff Chalk	Danian (Zone PO)/upper Maastrichtian (<i>P. grallator</i> Zone)	Olsson and Liu, 1993; Habib et al., 1996; Olsson et al., 1996
19	Braggs roadcut, Lowndes Co., AL	Clayton Fm./ Prairie Bluff Chalk	Danian (Zone NP1)/upper Maastrichtian (<i>M. prinsii</i> Zone)	Moshkovitz and Habib, 1993
20	Mussel Creek, Butler Co., AL	Clayton Fm./ Prairie Bluff Chalk	Danian (Zone PO)/upper Maastrichtian (<i>M. prinsii</i> Zone)	Moshkovitz and Habib, 1993; Olsson and Liu, 1993

APPENDIX 1

(Continued)

No. ^a	Location	Lithostratigraphy	Biostratigraphy	Source
21	Moscow Landing, Sumter Co., AL	Clayton Fm./ Prairie Bluff Chalk	Danian (Zone PO)/upper Maastrichtian (<i>D. galatea</i>)	Habib et al., 1996
22	Union Co., MS	Clayton Fm./ Prairie Bluff Chalk	Paleocene/upper Maastrichtian (<i>D. iris</i> Zone)	Kennedy and Cobban, 2000
23	Tippah Co., MS	Clayton Fm./ Owl Creek Fm.	lower Paleocene/upper Maastrichtian (<i>D. iris</i> Zone)	Sohl, 1960; Kennedy and Cobban, 2000
24	Hardeman and McNairy Co., TN	Clayton Fm./ Owl Creek Fm.	Paleocene/upper Maastrichtian (<i>D. iris</i> Zone)	Sohl, 1960; Russell, 1975
25	Crowley's Ridge, Stod- dard and Scott Co., MO	Clayton Fm./ Owl Creek Fm.	lower Paleocene/upper Maastrichtian (<i>D. iris</i> Zone)	Stephenson, 1955; Campbell and Lee, 2000
26	southwestern AR	Midway Gp./ Arkadelphia Fm.	Paleocene/upper Maastrichtian	Dane, 1929; Pitakpaivan and Hazel, 1994
27	Brazos River, Falls Co., TX	Kincaid Fm./ Corsicana Fm.	Danian (Zone PO)/upper Maastrichtian (<i>D. iris</i> Zone)	Hansen et al., 1987; Gale et al., 1999; Kennedy et al., 2001

^aNumbers correspond to those in figure 11. Litho- and biostratigraphy as reported in the source. The upper unit is listed first.

^bIncluded despite a large hiatus, probably due to the position of the core on the Cape Hatteras Arch.

^cMarine sediments overlying delta plain freshwater deposits.